Quality FARM DUGOUTS

Alberta
Government

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This publication is a product of Alberta Agriculture and Forestry. The goal of this publication is to help rural people manage dugout water supply and water quality.

The original version of this publication was developed as a cooperative project by a coalition of Canadian Prairie Provincial agencies under a working group called Prairie Water News. Prairie Water News was formed in 1990 to provide rural residents a reliable and consistent source of water-related information. The Prairie Water News group was dissolved in 2011 but did produce a biannual newsletter about water-related issues on the Canadian Prairies. Archived copies of these newsletters may be available by contacting any of the working group agencies. The Prairie Water News group consisted of:

- Province of Alberta, Alberta Agriculture and Forestry
- Province of Alberta, Alberta Environment and Parks
- Province of Manitoba, Ministries of Agriculture, Environment, Health and Intergovernmental Affairs
- Government of Canada, Agriculture and Agri-Food Canada, Prairie Farm Rehabilitation Administration
- Government of Canada, Fisheries and Oceans Canada
- Saskatchewan Research Council.

The purpose of this manual is to provide the latest research information on improving both the quantity and quality of dugout water. It identifies and explains general dugout planning, design, construction, treatment, and management practices. It also indicates practices to avoid, and attempts to dispel a few myths about dugout water management.

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How to Use this Manual

Quality Farm Dugouts contains nine modules including a number of worksheets that complement the text and add a very practical element to the manual's use. A pocket in the front cover stores example worksheets. A pocket in the back cover stores blank worksheets and can be used to store other important documents for your dugout, such as completed estimates, record forms, and personal contacts. Although certain topics will be of more interest and value than others, we recommend that you start with Module 1 and work through the manual systematically.

Features of the Manual

Sidebars

Sidebars in the narrow columns on each page contain specialized and important comments, considerations, and reminders.

Worksheets and Maintenance Schedules

One copy of blank worksheets and maintenance schedules are included in the pocket at the back of the manual. These forms enable you to calculate and collect important information to use in planning, designing, constructing, and operating a dugout water system. Examples of the use of each of the worksheets and schedules are included within the text and in the front pocket.

Bolded Terms

Bolded terms throughout the text are defined in the Glossary on page 119 of the manual.

Prompts

Prompts are symbols that direct you to carry out or avoid certain actions or practices.

Recommended practice or action.

Not recommended practice or action.

Remember!

Key concept, practice, or issue.

Dangerous practice, action, or issue!

Practice, action, or issue that requires caution!

Worksheet, exercise, or activity.

History

Today, many farm operations have several choices for obtaining water supplies. Some now even have access to pressurized and treated water through rural water pipelines. Despite these advances, dugouts continue to be an important part of many farm water systems.

Dugouts are an important water source on the Canadian Prairies for a wide range of uses including:

- irrigation
- greenhouse production
- pesticide spray mixing
- livestock watering
- aquaculture
- household water supplies
- human drinking water
- fire fighting

Different dugout uses demand different levels of water quantity and quality and, in large part, determine the size, shape, location, and type of management required.

Over the years, several agencies in all three Prairie Provinces have provided information and management advice to owners of dugouts. This information has been periodically updated as the result of 50 years of ongoing research. The provision of current dugout knowledge and management practices to dugout users helps to ensure that water is not a limiting factor in economic success or quality of rural life.

Understanding Prairie Dugouts

It is much easier to design, operate, and maintain high quality dugouts if you understand the natural processes that control them. This module explains some of these processes. Climate and landscape determine how much runoff will be captured by a dugout. Once the runoff is stored, the dugout provides an environment for a wide variety of plants, animals, and micro-organisms that can have a huge impact on water quality.

The Prairie Climate

Climate has an over-riding effect on water supplies. Three broad climate zones, as shown in Figure 2-1 Climate Zones, characterize the Prairie region:

The Prairie region is comprised of three broad climate zones.

- steppe
- continental
- sub-arctic.

The steppe climate is dry year-round, with cold winters and warm summers. The continental climate is wetter, with cold winters and cool summers. The sub-arctic climate is characteristic of the boreal forest. Winters are long and cold. Summers are short and cool. The majority of the Prairie grain belt is in the continental region. Southwestern Saskatchewan and southern Alberta, with the exception of the Cypress uplands, are within the steppe region. Very little agricultural land is contained in the sub-arctic region.

With the exception of the Alberta foothills, average annual precipitation across the Prairies increases from 300 mm in the southwest to 500 mm in the northeast. Most of this precipitation occurs as late spring and summer rains. Often storm events produce floods. Winter precipitation occurs as snowfall, which usually remains all winter, melts rapidly in early spring, and creates a runoff event.

Mean annual temperature generally decreases from southwest to northeast. Southern Alberta and southwestern Saskatchewan often experience warm winter winds, called Chinooks, which produce melting and evaporation of snow during winter months. The entire Prairie region experiences an annual water deficit whereby evapo-transpiration exceeds precipitation. Because of low precipitation and Chinooks, deficits are severe in the southwest. Large fluctuations in temperature and precipitation from year to year may produce periods of drought or extreme wet conditions.

Figure 2-1 Climate Zones

The Fishbone Diagram

Figure 1.2.3 Hazard or Not?

Recommended	Not Recommended

Do not store heavy containers on shelves that are above eye level.

Do not store knives with the blade facing up.

Do not store flammable materials near heat sources.

Do not store chemicals in unlabeled containers.

Dugout Water Quality

As previously noted, wells are generally preferred to dugouts because water quality in most dugouts is poor. Runoff water often brings dissolved and suspended materials that are detrimental to water quality, including:

- disease-causing organisms
- plant nutrients/dissolved fertilizers
- pesticides
- decomposed plant and algae material
- suspended sediment
- fecals, sediments, and paints
- salt minerals

A single liter of motor oil can make two million liters of water unfit for human drinking water.

The net result of contaminant loaded runoff is poor quality, dugout water. However, dugout water quality can be managed, improved, and treated to meet most farm needs. Attempts to manage or enhance dugout water quality must recognize and work with the natural biological and chemical processes occurring in the dugout. Good dugout management starts with the dugout watershed and extends right through to the final use.

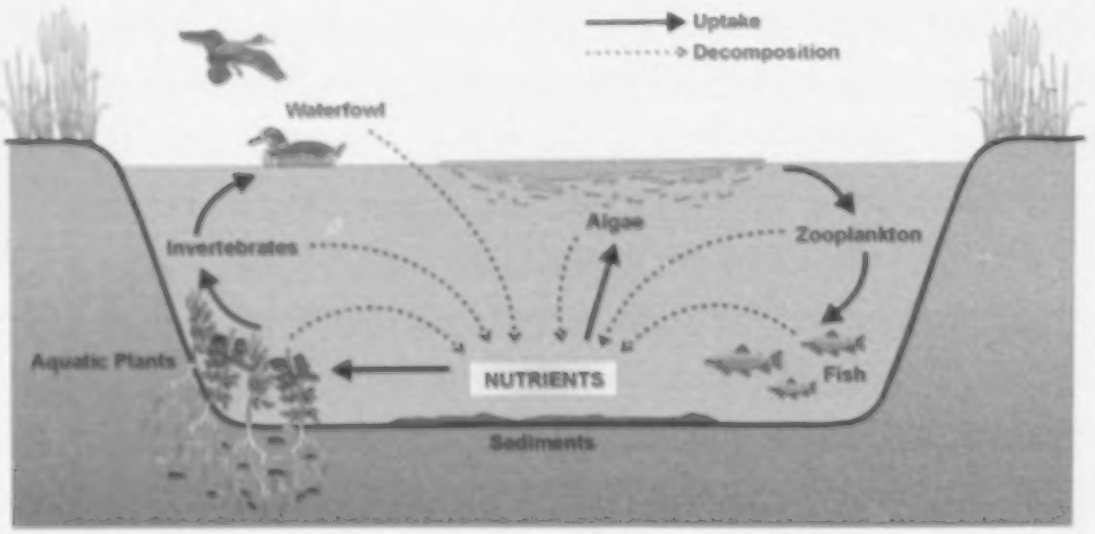
Biology of a Dugout

Many people see a dugout as a stagnant, lifeless body of water. Nothing could be further from the truth. As a newly constructed dugout fills for the first time, it is quickly invaded by a variety of organisms, including plants, microbes, insects, and animals, and develops its own unique ecosystem. The fertile soils in which most dugouts are located contribute nutrients for plant growth. The rooted plants and algae represent an important food source for tiny animals called zooplankton. Through the food chain, the zooplankton become a source of food for insects that ultimately become a source of food for amphibians and fish. In fact, a dugout is a living ecosystem driven by natural cycles and processes.

The biology of a dugout is similar to the cycle within any other small body of water. Each summer, warm temperatures and long sunny days produce an explosion of plant and animal growth. In daylight, plants consume nutrients and pump oxygen into the water; at night, oxygen production stops and respiration consumes dissolved oxygen which can result in low dissolved oxygen levels. When they die, microorganisms decompose their tissues. This decomposition process consumes oxygen. On hot, still days biological activity is high and there is little oxygen added by wind-driven mixing of the water. In winter when the surface is sealed by ice, oxygen levels can also become very low. When this occurs, anaerobic organisms that do not use oxygen take over the decomposition process. Anaerobic activity releases many unwanted compounds into water. These include forms of iron and manganese that produce coloured water and unpleasant smelling swamp gases and substances such as hydrogen sulfide and geosmin. Odourless gases such as methane and carbon dioxide may also be released. As these microorganisms die, their decomposition also adds nutrients to the water body that become available to plants to begin the cycle again.

A dugout is a living ecosystem subject to natural cycles and processes.

Figure 2-3 Simplified Nutrient Cycle



Many forms of plant life thrive in dugouts as shown in Figure 2-3 Simplified Nutrient Cycle. Some species are rooted in the dugout but are totally submerged, such as Northern Watermilfoil and White Waterbuttercup. Others inhabit the margins where they are rooted in the sediments but hold their vegetation above the water. Cattails and reeds are examples of this type of plant. Although only one of the many forms of plant life in a dugout, algae get a lot of attention. This is primarily due to the problems they cause in a water supply. Algae can be present in dugouts but go unnoticed most of the time. When conditions are favourable, however, they can reproduce very rapidly and cause a "bloom". Algae blooms cause a variety of problems:

Algae in dugouts are of particular concern with algae blooms causing several problems.

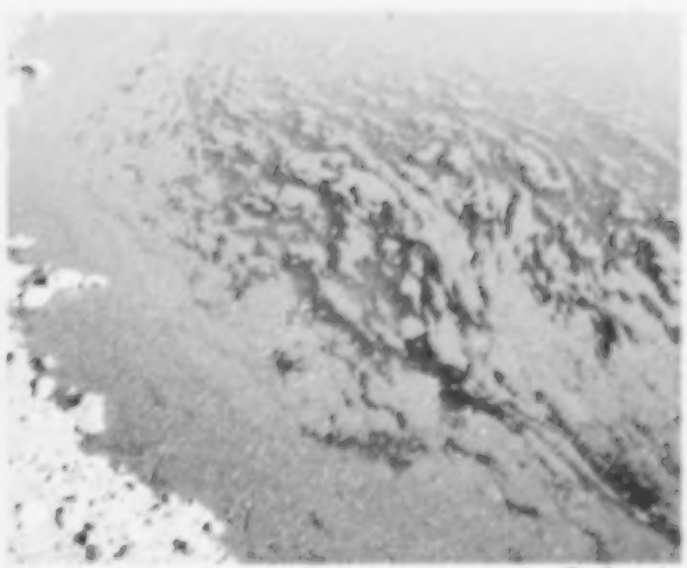
- toxins in the water
- water turbidity
- tastes and odours
- clogging of filters
- ineffective disinfection treatment
- formation of toxic chlorination by-products
- fluctuating oxygen levels between day and night, resulting in fish kills.

Cyanobacteria are often incorrectly referred to as blue-green algae. It is bacteria, not algae. The formation of toxins by **cyanobacteria** is of the greatest concern. Some are capable of producing toxins that can damage the liver, nerves, lungs, and hearts of livestock. Cyanobacteria float near the water surface and wind action blows them to the side of the dugout. When livestock water directly at the edge of a dugout, they may be exposed to high concentrations of cyanobacteria in the water. Cases of livestock deaths due to cyanobacteria have occurred in all the Prairie Provinces.

Growth of cyanobacteria is greatest when the water is warm and concentrations of nutrients, especially phosphorus, are high. It is not easy to distinguish between cyanobacteria and harmless green algae as shown in Figures 2-4, 2-5, 2-6, and 2-7. Positive identification requires training and use of a microscope. When an algae bloom occurs in water used for livestock, it is best to exercise extreme caution. Little corrective action is possible once a cyanobacteria bloom has occurred. The most effective strategy for reducing the risk is to manage a dugout so the conditions that induce large populations do not develop. Much of this manual is devoted to this topic.

Ron Zuromski

Figure 2-4 Green (Filamentous) Algae
There are many types of green algae. Shown here is a filamentous type which is characterized by long threads or filaments of cells attached together and found floating as a mat on the surface. It is commonly called pond scum.



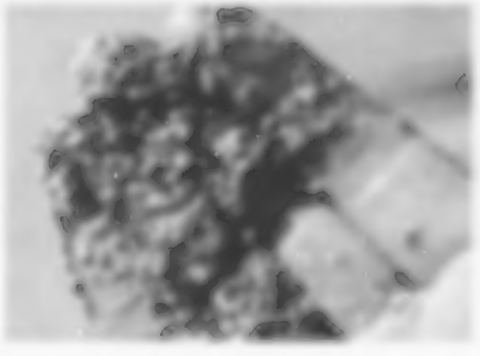
Ron Zuromski

Figure 2-5 Cyanobacteria
There are many types of cyanobacteria. They are microscopic in size but become visible when large populations develop forming what is termed a "bloom". Some types are extremely toxic to humans and animals.

Figure 2-6 Cyanobacteria
One type of cyanobacteria is highly visible due to its "grass clipping" appearance with pieces measuring from 1/2 to 3/4 inch (13-19 mm) in length.

Cyanobacteria are often excessively referred to as blue-green algae. It is bacteria, not algae.

Figure 2-7 Duckweed
Duckweed is a readily identified oval shaped plant that floats on the water surface and forms a mat that can cover the entire deposit.



The Life Span of a Dragonet

Planning

Planning Farm Water Supplies

Although a well-planned and designed water system may cost more initially, it will ultimately save you money. You can avoid costly changes to correct future problems.

The initial planning steps include:

- Determination of Water Requirements
  The first step in planning is to determine the amount of water required. Estimating future needs should take into account any anticipated changes such as an expansion or diversification of farm activities.

Make sure you carefully plan your water system. You will need to determine water requirements, take an inventory of water sources, and plan for land use practices that protect water supply.

- Inventory of Water Sources
  The next step is to take an inventory of all water sources. Many farms use more than one water supply. Account for production rates, storage volumes, and any previous problems with water quantity or quality for each source. If the dugout is to be the only source of water, uncertainty of runoff volume should be factored into the sizing calculation. Because of frequent drought on the Prairies, it is recommended that all dugouts be constructed to hold at least a two-year water supply. In situations where the dugout is not critical to operations or alternate supplies are readily available, a smaller dugout may be chosen. Calculations in this manual, however, focus on the two-year supply.

- Land Use Planning to Protect Water Supply
  Activities within a watershed have a large impact on water quality and quantity. Evaluating and adapting farm practices where it affects runoff can do much to increase dugout utility.

Regulatory and Funding Issues

Before constructing a new dugout, it is important to be aware of legal restrictions that may apply. Ownership of surface and groundwater is vested in the provinces. Provincial approval is required for the following uses:

- aquaculture
- commercial uses
- municipal uses

- tank-loading
- irrigation
- environmentally sensitive areas such as sloughs, streams, areas of wildlife habitat, etc
- areas short in water such as parts of the South Saskatchewan River Basin.

In most jurisdictions, municipal and provincial, there are also requirements for minimum setback distances from public roadways. Stocking of dugouts with fish is controlled to minimize the risks of discharges that could introduce disease and non-native species of fish into natural waterways.

Before constructing a dugout, consult appropriate authorities to ensure compliance with existing regulations. Obtain approvals well in advance to avoid delays in construction.

Provincial governments offer technical assistance for the construction or improvement of dugout water supplies. Financial assistance may be available for some projects. Regulations and funding vary significantly between provinces. Provincial regulation summaries are provided in Appendix 1 Provincial Regulations.

Watershed Runoff Potential and Water Quality

The size of the drainage area or watershed is the most important consideration when determining potential runoff into a dugout.

Both the quantity and quality of water are affected by the characteristics of the drainage area and the activities that take place within it. The most important characteristic in determining potential runoff into a dugout is the size of the drainage area or watershed. In addition, soil type, land use, topography, and vegetative cover all influence the total quantity of water that will flow into a dugout.

Watershed Runoff Potential and Dugout Sizing

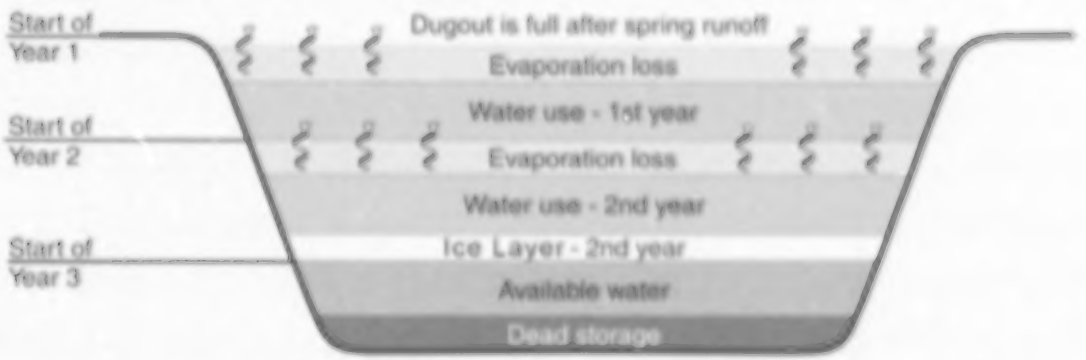
This section discusses factors that should be considered when selecting a site for your dugout. It is essential that a dugout be located to capture the quantity of water required. There are many considerations when choosing a site. Inevitably, some trade-off between conflicting factors will be required. However, it is worth the time and trouble to find the best location for a dugout that will be in use for many years.

Dugout Sizing

Dugouts fill with runoff from the surrounding land. The most important factors to consider in sizing are the potential amount of runoff that will be captured, evaporation loss, and the shape and dimensions of the dugout.

Figure 3-1 Dugout Size vs. Available Water illustrates the necessity of sizing dugouts properly so they provide a dependable source of water. In this example, the dugout has received no runoff water in two years. The cross-sectional view shows how the supply of available water is reduced by farm use, lack of runoff, evaporation, and ice formation in winter. In addition to uses and losses, the water at the bottom of the dugout will be of such poor quality that it is rated as dead storage and unavailable for use.

Figure 3-1 Dugout Size vs. Available Water



Supply of available water is reduced by farm use, lack of runoff, evaporation, and ice formation.

Runoff volume is determined by the amount and timing of snowmelt or precipitation, plant vegetation, soil type, soil moisture, and topography. The smaller the quantity of runoff expected in an area, the larger the contributing area must be to fill a dugout. In some dry regions of southeastern Alberta and southwestern Saskatchewan, more than 2000 acres (800 ha) of land are required to produce enough runoff to fill a dugout with a capacity of one million Imperial gallons (4.5 million litres). In wetter areas of southeastern Manitoba, less than 25 acres (10 ha) would be required to supply the same volume.

Figure 3-1 Runoff Map shows the approximate acres of land required to provide runoff water volume equal to or greater than one million Imperial gallons (4.5 million litres). Runoff varies a great deal from year to year. The map is based on long-term runoff data. In eight out of every ten years, the specified amount or more runoff occurred. In two out of ten years, there was less runoff. The uncertainty of runoff should be kept in mind when planning dugout size. If a particular watershed is too small to provide enough runoff, you have two choices:

- dig a larger watershed
- find an additional watershed and build a second dugout.

When faced with these choices, it is a good idea to consult a water specialist. Evaporation rate is an important factor in dugout sizing that varies widely between regions. Figure 3-2 Evaporation Zones is a map of evaporation loss zones in the Prairies. The greater the evaporative losses, the greater the storage volume must be to guarantee continuous supply.

Consider both the area of land required to provide adequate runoff water and evaporative rate when you plan your dugout size.

The shape of a dugout has important implications for both the quantity and quality of the stored water. Historically, most dugouts have been about 10 feet (3.7 m) deep. However, new larger structures are being excavated to depths of 15, 18, and 21 feet (4.6, 5.5, and 6.4 m) and even deeper.

A deeper dugout is more efficient because it has less surface area for the same capacity and thus loses less water to evaporation. This can have a significant effect on the required volume. For example, an Evaporation Zone 4, a 21 foot-deep (6.4 m) dugout can be constructed with approximately two-thirds the volume of a 15 foot (4.6 m) deep dugout and provide the same amount of available water. Deeper dugouts tend to have better water quality, particularly in winter. There main concerns with deeper dugouts are high water tables, seepage losses, and increased safety hazard.

During winter, dugouts freeze and some of the stored water becomes unavailable for use. Ice can reach up to 2 to 3 feet (.6 – .9 m) in thickness, which may represent up to 30 to 40 per cent of total volume. Figure 3-3 Dugout Size vs. Available Water shows the amount of stored water that becomes unavailable for use during winter.

Figure 3-2 Runoff Map

In general, the colder the climate, the thicker the ice, and the greater the loss of available water. However, this can be offset by differences in snowfall. Snow cover on the ice insulates the water from further freezing. Figure 3-4 Ice Thickness Map shows average expected ice thickness on small water bodies in different parts of the Prairies.

Figure 3-4 Ice Thickness Map

The climate and runoff information given previously is used to plan the size of a dugout for any location on the Prairies.

Figure 3-5 Dugout Sizing Example illustrates an example of the dugout sizing process for the Joe Agricola Family Farm at Stettler, Alberta. Remove the completed example from the pocket inside the front cover of the manual and work through it. **Completing this exercise can potentially save you thousands of dollars in construction costs.** Carefully follow the steps and calculations to understand the process. Blank forms for accurately sizing your farm dugout are located in the pocket inside the back cover of the manual.

Figure 3-5 Dugout Sizing Example

Water Quality and Watershed Management

Good watershed management is the first line of defense for ensuring good quality dugout water. Using what are termed Beneficial Management Practices or **BMPs** within the catchment or runoff area can minimize the possibility of dugout water contamination. Contamination occurs through a number of processes.

Contamination of the watershed can come from plant nutrients, pesticides, livestock confinement areas, waste disposal sites and water and wind erosion.

- Plant nutrients from natural sources, fertilizers, and manure entering a dugout in field runoff stimulate the growth of plants and algae.
- Pesticides can contaminate water when stored improperly, mixed carelessly, or spilled. They can also be present in runoff water from recently sprayed fields. Airborne drift clouds are able to travel long distances and may be deposited in streams, lakes, and dugouts.
- Runoff from livestock confinement areas is typically rich in nutrients and likely contaminated with bacteria, viruses, and parasites.
- Poorly sited waste disposal sites or inadequate storage facilities can contribute fuels, paints, solvents, and other hazardous chemicals to dugout in-flow water.
- Water erosion loads runoff water with soil, nutrients, and pesticides that may end up in dugouts. Long, steep slopes in the landscape, that are not under perennial cover, are very susceptible to water erosion events. Even relatively level fields can be subject to severe water erosion during spring runoff and heavy rainfall events. Silty soils are particularly susceptible to water erosion. Suspended solids in runoff water cause turbidity in dugouts, causing problems in water distribution systems and increasing the difficulty and cost of treatment.
- Wind erosion may lead to contamination of dugouts when soil is blown into the water from adjacent fields or livestock areas. Sandy soils and heavy clay soils are most susceptible to wind erosion.

Beneficial Management Practices in a Watershed

The following BMPs can reduce erosion and contamination of inflow water as illustrated in Figure 3-6 Watershed with Beneficial Management Practices:

- Agricultural fields in annual cultivation are prone to wind and water erosion, particularly when residue cover is poor in winter and early spring. Soil surface protection practices are highly effective ways of preventing erosion and include:
  - seeding erodible land to perennial forages
  - using conservation tillage
  - maintaining crop residues in the fall
  - using winter cover crops
  - using crop rotations that follow low-residue crops with those with higher straw-yield.
- Practices that slow water runoff velocity and reduce water erosion:
  - grassing waterways
  - contour planting that place rows perpendicular to the slope of a field.
- Practices that slow wind velocity and reduce wind erosion and include:
  - strip farming consisting of alternating bands of annual and perennial crops
  - planting and maintaining shelterbelts.
- The amount of fertilizers applied in a watershed can be minimized by proper nutrient management planning. Nutrient management is based on application of only enough fertilizer to make up the difference between the amount available in the soil and the crop requirement.
- Total amounts of pesticides applied to a watershed can be minimized through the principles of **integrated pest management** or "IPM". IPM is a pest management system using the application of a variety of management practices and control measures.
- Remote watering systems prevent livestock from having direct access to a dugout, or to other areas in the watershed that directly contribute runoff to a dugout.
- Good manure management protects water from contamination. As with chemical fertilizers, manure should not be applied in quantities that provide plant nutrients in amounts that exceed crop requirements.
- Good livestock management prevents over-grazing, which can leave soils susceptible to erosion. This can be prevented by using a rotational grazing system.

Figure 3-6 Watershed with Smorbrian Management Practices

Diagonal Sliding

Flexibility in Water Use

Flexibility in Electrical Power

Time

Flexibility in Other Power Sources

Design and Construction

Dugout Design

The construction and management of a dugout can have a large impact on water quality. Design options allow dugout owners to control inflow and permit only the highest quality water to be stored. Once runoff has been collected, good management can prevent water quality from deteriorating as illustrated in Figure 4-1 Dugout Design and Beneficial Management Practices.

Slopes

Historically, dugouts on the Prairies were constructed with 1.5:1 side-slopes and 4:1 end-slopes. The soil conditions and the construction equipment available largely dictated these specifications. Equipment capable of digging deeper excavations with steep end-slopes is now readily available. Steeper slopes reduce the growth of cattails and other aquatic plants that contribute organic matter and plant nutrients to the water. However, a dugout with four steep sides can be a safety hazard. It is recommended that dugouts be fenced to exclude livestock, and a flotation device should be available and used to protect children and adults from drowning.

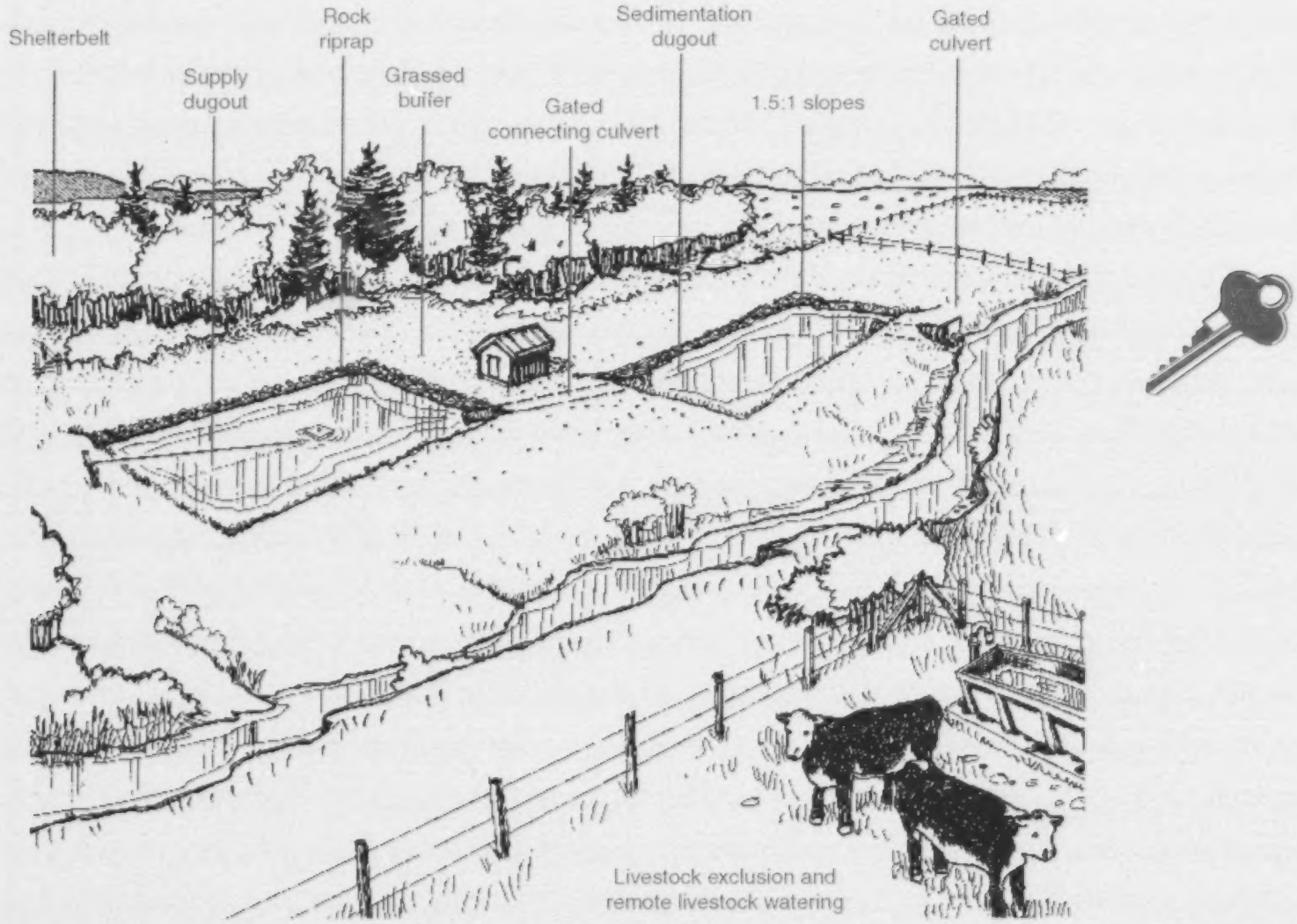
Erosion Control

Spoil piles are created during the construction of a dugout. If spoil piles are located at the edge of a dugout, they may erode or slump into the water. Spoil piles may also act as a windbreak and reduce wind mixing which incorporates oxygen into the water. It is recommended that the spoil piles around a dugout be leveled to maintain bank stability, and grassed to provide a filter that reduces the entry of soil and nutrients. Although the ideal width of a grassed buffer varies between sites, the recommended **minimum** is 33 feet (10 m).

Control erosion by leveling and grassing spoil piles and protecting dugout sides and end-slopes.

In windy areas of the Prairies, dugout life is increased when the dugout sides and end-slopes are protected to prevent soil erosion by wave action. This can be done with a combination of grass, rocks (often termed **riprap**), heavy plastic, or **geo-textile** materials. Riprap can also be effective at discouraging muskrats from moving in.

Figure 4-1 Dugout Design and Beneficial Management Practices



Inlet Structures

A dike and gated culvert inlet can be built to give the owner control over the inflow water. Poor quality water can be prevented from entering a dugout. The first flow of water from cultivated fields during snowmelt is typically high in dissolved nitrogen and phosphorus. Excluding this initial volume of water can improve water quality. Diverting flow away from the dugout is only practical where it is certain that there is more than enough runoff to fill the dugout. After the dugout has filled, the inlet should be blocked. This prevents sediment and nutrients carried by runoff from spring and summer rains from entering the dugout. If water is pumped into a dugout, prevent bank erosion from occurring at the discharge point.

Livestock Exclusion

Allowing animals to water directly from a dugout degrades water quality and drastically shortens the life of a dugout. Nutrients from manure stimulate plant growth and hoof action destroys dugout banks. It is recommended that all dugouts be fenced off and water supplied to livestock through remote watering systems. This protects the dugout, its water quality, and the livestock themselves. Many options are now available for supplying water to livestock on remote sites. Where a dugout is far from electricity, alternative power sources including windmills, solar panels, gravity systems, and animal powered devices, such as "nose pumps", are reliable and affordable options.

Design your dugout to exclude cattle; supply water to livestock through remote watering systems.

Sedimentation Dugouts

Much of the unwanted material that enters a dugout in runoff is suspended. If water is allowed to stand, much of the suspended soil and organic matter will sink to the bottom. In locations where the soil is highly erodible, and the landscape and costs permit, two dugouts can be constructed adjacent to one another. The first will act as a settling pond. High quality, surface water can then be either pumped into the supply dugout or allowed to flow in by gravity.

In a situation where an existing dugout is being replaced with a new one, it may be useful to retain the original as a sedimentation structure. The new dugout can often be positioned to fill with water that has been allowed to settle in the old dugout. This can be more beneficial and economical than cleaning out the original dugout.

Dugout Construction

Pre-Construction Testing

In many areas of the Prairies, sand, silt, and gravel layers occur close to the soil surface. Many of these layers can contain small amounts of groundwater that has seeped down from the surface. While many people installing new dugouts believe it is good to have water seeping into the dugout, these lenses of sand and silt can create many problems. They may provide a path for water to seep out of the dugout leading to depleted water supplies during periods of drought. In addition, highly mineralized groundwater seeping into the dugout can adversely affect the quality of trapped runoff water.

To ensure that sand lenses are avoided, dig at least five or six test holes or pits prior to excavating the dugout. Dig these holes around the outside and within the proposed dugout area to a depth of 4 to 5 feet (1.2 – 1.5 m) deeper than the proposed dugout bottom. They should not be located more than 100 feet (30 m) apart to minimize the possibility of missing intermittent sand layers that may occur. This testing will also identify other problems including shallow water tables and bedrock, as well as the most suitable construction equipment.

Large Scale Sealing Methods and Materials

If sand layers are generally in the area and no suitable site can be found, several additional test holes or pits may be required to determine the extent of the sand layers and help determine how to seal these areas. In some cases, it may be best to abandon the site and try to locate a dugout in more favourable soil conditions. In other cases, it may be simply a matter of over-excavating the areas of concern and backfilling with expanding clay to provide the proper seal.

For larger areas, the potential for seepage must be addressed at the time of construction. If it appears that seepage will be a problem, then most sealing methods will require flatter slopes of approximately 3:1 for the sealing treatment to be applied.

Consult a professional soil or water specialist if large scale workings is required.

Figure 4.2 Packed Straw Pad on

Clay Lining

If a source of good quality clay is available, it may be feasible to clean and spread the clay onto the pond bed using normal agricultural equipment to provide the required clay layer. The percentage of the clay in the soil will vary depending on the geological formation in the area. Soil tests can be carried out to determine the suitability of the soil for clay lining. Generally, soils containing between 20 and 40 per cent clay are suitable for pond lining. Soils containing more than 40 per cent clay may crack when dry and soils containing less than 20 per cent clay may be too porous to form a watertight seal.

Geotextiles

Geotextiles are a relatively new material. They have a role in many fields but in pond construction they are used as a separation layer between the clay liner and the stone layer. This prevents the stone from penetrating the clay liner and causing leakage. Geotextiles are also used to protect the clay liner from damage during the placing of the stone layer.

Bentonite (Sodium Silicate)

Bentonite is a clay material which swells when it comes into contact with water. It is used to seal small leaks in existing ponds. Bentonite is applied to the surface of the pond and then worked into the soil by harrowing. The pond is then refilled with water. The bentonite swells and seals the leak.

Plastic Liners

Plastic liners are available in a variety of materials. They are expensive and need to be installed according to the manufacturer's instructions. Some plastic liners are vulnerable to damage by sharp objects and must be protected by a layer of sand. Plastic liners are also prone to damage by rodents. Plastic liners are usually covered with a layer of stone to protect them from damage by animals and from the effects of sunlight. Some plastic liners are vulnerable to damage by sunlight and must be covered with a layer of stone. Plastic liners are also prone to damage by rodents. Plastic liners are usually covered with a layer of stone to protect them from damage by animals and from the effects of sunlight.

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The main disadvantage of this type of unit is the reach of the boom, and consequently the width of the dugout that can be conveniently built. Some of the newer units, with extended booms, are able to dig dugouts 60 to 70 feet (18 - 21 m) in width. Due to the shorter reach, the soil removed is piled very close to the edge of the dugout. This can lead to collapse of the banks due to the extra weight of earth. Because it is impractical to move and spread the excavated material with a trackhoe, the spoil pile presents a problem. For wider and deeper dugouts, the trackhoe can move the excavated material a second time. A better option is to use a dozer or a large loader to move the piles of excavated soil back away from the edge of the dugout. The fill can be used to low areas or to establish dikes to control the flow of water.

Figure 6.6 Dragline

Dragline

While the dragline shown in Figure 6.6 Dragline has been around for many years, its use in digging dugouts has declined in recent years due to the difficulty of transporting it. It is slower and less versatile than a trackhoe. Due to long reach and flotation, the dragline is ideally suited for installing dugouts in swampy or low-lying areas. Draglines can excavate dugouts up to 70 feet (21 meters) in width. In addition, because of the reach, spoil banks can be kept away from the edge of the dugout but, as with the trackhoe, it is impractical for the dragline to move and spread the excavated material to other areas.

Figure 6.7 Scraper or Buggy

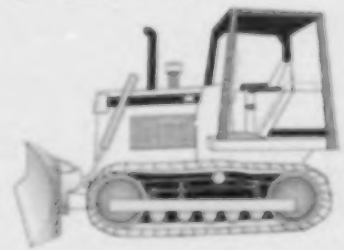
Scraper or Buggy

Motor scrapers or "buggies" as shown in Figure 6.7 Scraper or Buggy are large units that are used to remove, carry, and deposit the earth from the dugout excavation. Buggies are mounted on rubber tires and have the advantage of being able to move large amounts of earth very quickly. They can easily move the material to other areas for landscaping and filling purposes. As the hole becomes deeper, and the soil more compacted, this type of unit may encounter problems with traction and in some cases may require a cat with a ripper tooth to loosen the soil before excavation. Track-type scraper units are slow but have better traction and can work in more varied soil conditions. The main disadvantage of these units is the need for gently sloping embankments to allow entry and exit from the excavation. It is recommended that these flat slopes be integrated with a trackhoe.

Dozer

While a dozer as shown in Figure 4-6 Dozer can excavate a dugout alone, it is a slow process and will result in large spoil piles at both ends of the dugout. Wet soil conditions can cause delays and problems for a caterpillar. However, due to its traction, it can operate in a variety of soil types. As with other scraping equipment, dozers cannot construct steep slopes on all sides. Gently sloping end-slopes are required for entrance and exit from the excavation. The end-slopes should be steepened with a trackhoe.

Figure 4-6 Dozer



Selecting a Contractor

Experience

While digging a dugout may sound easy, how it is built will determine how long it lasts and how well it performs. For example, the slope of the sides will depend largely on soil type. The more silt or sand a soil contains, the flatter the slopes must be in order to prevent collapse. Similarly, sandy pockets or veins encountered during excavation may require sealing to prevent future leakage. An experienced contractor will recognize soil problems and inform the land-owner of possible solutions. Further technical assistance can be obtained from a soil or water specialist.

A dugout is more than just a hole in the ground.

References

A good contractor should be willing and able to provide a list of past clients. These references should be checked to see not only if the previous clients were satisfied with the work completed, but also how the dugout is operating and if any problems have arisen due to construction techniques utilized.

When you select a contractor to construct your dugout, look at such things as experience, references, equipment availability, time, and cost.

Equipment

The availability of equipment in the area will be an important factor in choosing a contractor. The equipment to be used should not only appear to be in good mechanical shape, but must also be appropriate for the site. The choice of the wrong equipment can lead to a very expensive dugout and one that may not be completed to your satisfaction.

Dugout Finishing

It is recommended that excavated material from the dugout be leveled, spread, and topsoil replaced. The final steps are to install any culvert inlets and trenches for water and airlines, replace the topsoil, and seed grass to a buffer area around the dugout and the in-flowing runoff channels.

Costs

Depending on construction conditions, certain equipment may be more expensive than others. To ensure the best price available, quotations should be obtained from several contractors whenever possible. Quotations are normally given in price per cubic yard or cubic metre of material removed. If the excavated soil is to be moved and spread to fill in low areas or form dikes, the cost should be kept separate from the dugout quote. As with any quote for work, it should always be in writing to eliminate any misunderstandings. Check to see if equipment transportation costs are included in the quoted price. Depending on the type and location of the equipment, transportation costs may be a major addition to the costs of excavation.

Time Factor

As with any type of contracted work, acceptable times for starting and finishing the job should be spelled out before any contracts are signed or work started. In many cases, availability of equipment will be the determining factor as most contractors are extremely busy in the fall of the year. Better prices may be possible if the work can be done in early summer, during the "off season".

Construction Estimate

The first step is to get two or three dugout construction estimates. A sample construction estimate is provided in Figure 4-7 Construction Estimate to illustrate the important information that should be obtained from a contractor. All agreements for work should be in writing and signed by both parties. Written contracts help eliminate any misunderstandings as to specifications, timing, and costs. Remember that ultimately you are responsible for any approvals needed to build the dugout and its potential effect on natural waterbodies or downstream landowners. The example is based on the Joe Agricola farm dugout that was used in the Planning Module as an illustration of the use of the Dugout Sizing Worksheets. Carefully read through the completed example. A blank copy of the Dugout Construction Estimate is included in the pocket at the rear of the manual.

Figure 4-7 Construction Estimate

Dugout Construction Estimate Worksheet

This worksheet lists the items that a producer should discuss with a dugout construction contractor. A clear understanding between both parties is crucial so there are no misunderstandings or false expectations. Dugouts are far more than a deep wet hole in the ground.

Dugout Owner: *Joe Agricola* Dugout Contractor: *Dugouts R' Us*

Address: *Stettler, Alberta* Address: *Stettler, Alberta*

Dugout Location: Qtr *SW* Sec *6* Twnshp *39* Range *19* Meridian *W4*

Proposed Starting Date: *October 15, 2015* Proposed Completion Date: *October 22, 2015*

Proposed Dugout Use: Household *X* Livestock *X* Irrigation _____ Recreational (i.e., fish) _____ Other _____

Check Location of Underground Utilities: *Contact Alberta One-Call utility company to mark lines October 7, 2015*

Pre-construction testing: Test holes or test pits to identify potential problems including sand or gravel (i.e., seepage), high water tables, or shallow bedrock No. of test holes or pits *2* Depth of testing *25 ft.*

Design Considerations for Dugout: Depth *21 ft* Width *100 ft* Length *330 ft* Volume *16,000 yd³* Side slops *1.5:1* End slope *1.5:1*

Runoff or Flood Control: *A dike will be constructed around the dugout with a gated inlet to control runoff into the dugout.*

Seepage Control or High Water Table Conditions: *None expected – testholes will confirm.*

Types of Construction Equipment: Trackhoe *$175/hr* Dozer *$140/hr* Scraper _____ Dragline _____ Buggy _____ Other _____

Equipment Transportation Costs: *0.0*

Dugout Construction Costs:

(a) pre-construction testing	$ *175.00*	/hour	x	*2*	hours	= $	*350.00*
(b) stripping top soil	$ *140.00*	/hour	x	*2*	hours	= $	*280.00*
(c) excavation costs	$ *2.50*	yd³	x	*16,000*	yd³	= $	*40,000.00*
OR	$ _____	/hour	x	_____	hours	= $	_____
(d) seepage control	$ _____	/hour	x	_____	hours	= $	_____
(e) spread excavated material	$ *140.00*	/hour	x	*10*	hours	= $	*1400.00*
(f) dike and gated culvert inlet (i.e., flood control – optional)	$ *175.00*	/hour	x	*1*	hours	= $	*175.00*
(g) trenching water and air lines and install wet well	$ *175.00*	/hour	x	*2*	hours	= $	*350.00*
(h) topsoil replacement	$ *140.00*	/hour	x	*2*	hours	= $	*280.00*
(i) topsoil preparation and seed to grass						= $	_____

Transportation and Construction Costs $ *42,835.00*

Tax $ *2,141.75*

Payment Schedule *Within 30 days of dugout completion* Total Cost $ *44,976.75*

Operating Systems

Engelgrenset Systemsys

Innsidn Systemsys

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Figure 3.1 Floating Intake

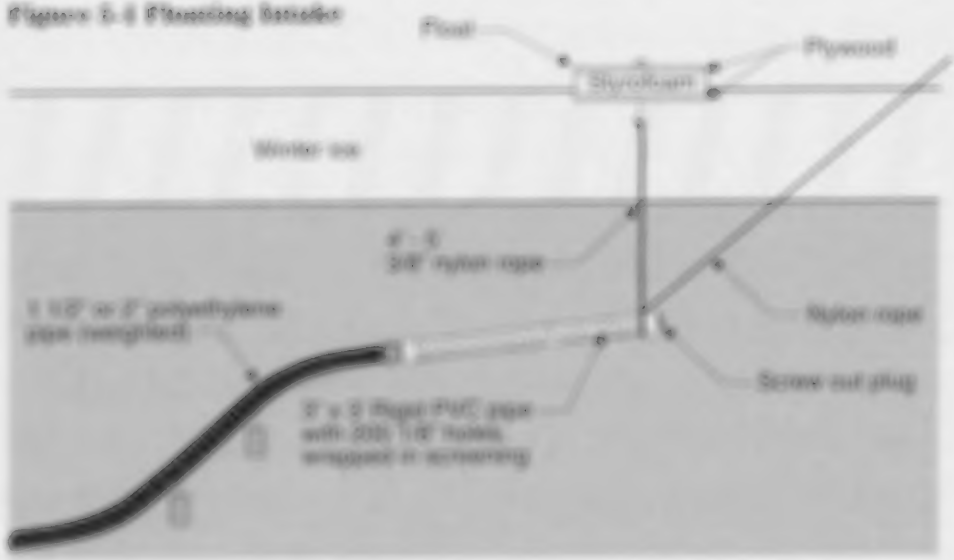


Figure 3.2 Submersible Pump and Intake System

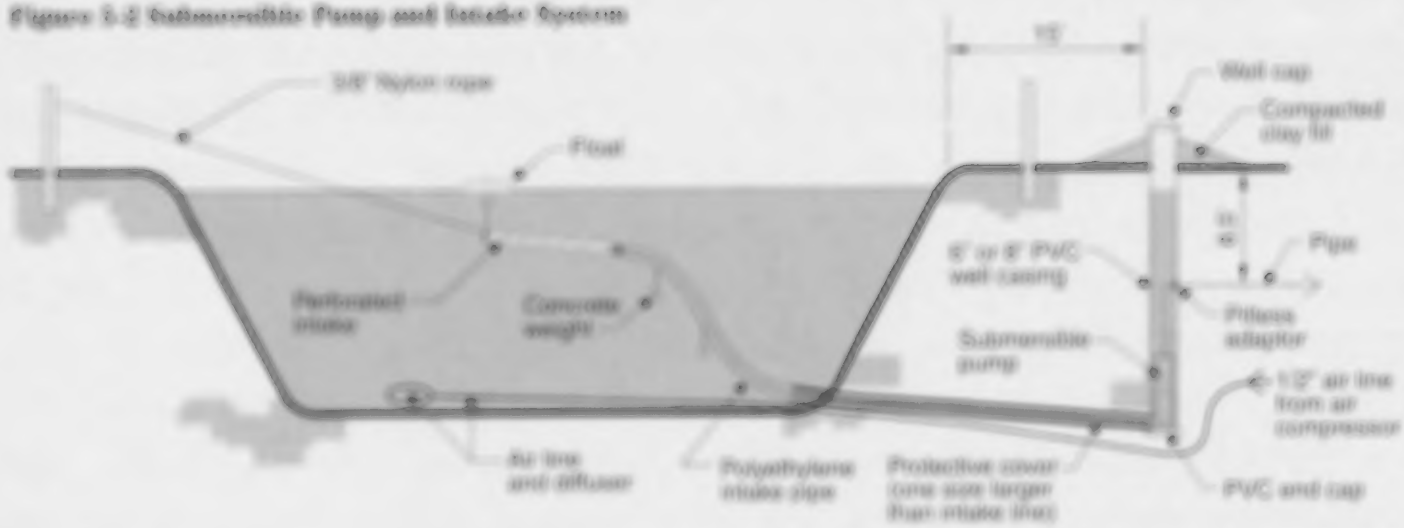
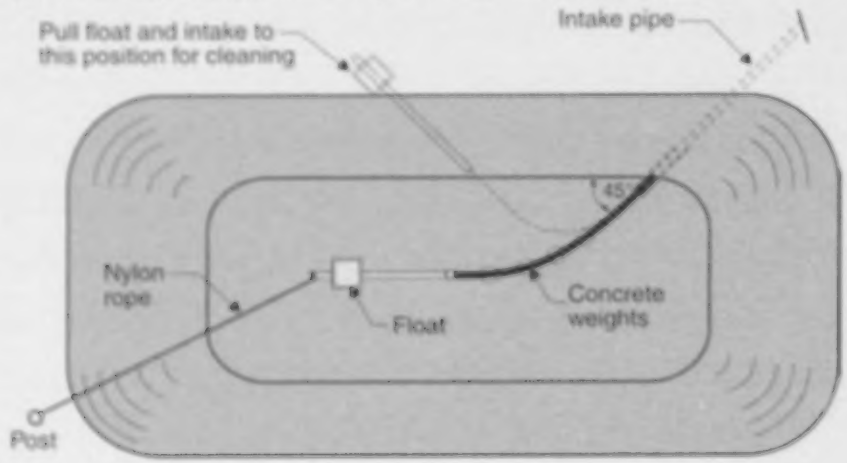


Figure 5-3 Plan View of Intake System

Figure 5-3 Plan View of Intake System shows a plan view of a dugout and the intake installation. The intake pipe should enter the dugout on a 45 degree angle to reduce the chances of kinking when the intake is pulled to shore for maintenance.



Other Intake Systems

Over the years, other types of water intake systems have been tried for dugouts. They are not recommended. Two common but unsatisfactory systems are:

1) Gravel infiltration trenches

Gravel-filled trenches between the dugout and a wet well beside the dugout have been unsuccessfully tried in the past. **They are not recommended.** The trenches can be effective filters for several years but will eventually fail due to plugging of the spaces in the gravel with soil, plant material, microorganisms, and biofilms. Flows to the wet well are inevitably reduced. Due to high levels of biological activity in the trench, oxygen levels fall which leads to the release of hydrogen sulphide gas. These conditions produce black smelly water in the wet well. It is also common to see a ten-fold increase in total dissolved solids, and greatly increased problems with iron, manganese, and hardness due to leaching of dissolved minerals from the gravel material. The only solutions are re-excavation and replacement of the gravel every few years, or replacement with an intake pipe.

2) Dugout bottom intakes

Large 4 to 12 inch (10 - 30 cm) horizontal piping has been used to convey water from the bottom of the dugout to a wet well. Although these systems do not plug, poor water quality is a problem. Unless the dugout is continuously aerated, the poorest water quality is always near the dugout bottom. Large open-ended pipes often result in water bugs entering the wet well, pumps, and distribution system. In some cases, bugs can plug impellers on pumps and screens. Avoiding this problem requires installation of screens around the dugout intake or the pump intake in the wet well.

Avoid using gravel infiltration trenches and dugout bottom intakes.

Wet Wells

A wet well is usually required beside the dugout to permit easy access to the pump. The water flows by gravity into the wet well as water is pumped from the well. For many years, two to three foot diameter, steel culverts were used for wet wells. Large diameter wells allow for some settling of solids to take place. However, recent monitoring of these installations has shown that dissolved oxygen levels are much lower in the wet wells than in the dugout water. The reasons for this include the large water storage capacity of wet wells and slow replenishment with fresh dugout water. Conditions in these wells can be similar to those that develop in gravel trenches: hydrogen sulfide gas formation, lower pH, and a high concentration of nutrients at the bottom of the wet well.

To avoid the problems associated with a large diameter wet well there are several options:

- Hire a vacuum-truck to come in every few years and suck out the black decayed plant material and sediment at the bottom of the wet well. It is very important that vacuum equipment be clean. A dirty hose can contaminate the wet well.
- For jet pump installations, elimination of the wet well is desirable with the intake assembly installed directly below the float in the dugout.

- For new submersible pump installations, a smaller diameter, 6 to 8 inch (15 – 20 cm) PVC well casing and pitless adapter are the best option. The smaller diameter PVC casing can also be installed inside an existing larger wet well. A smaller well has a steady supply of fresh dugout water and thus eliminates the poor water quality associated with larger wet wells. The PVC casing will last much longer than steel culverts which eventually corrode.

Pumps

There are many types and sizes of pumps for dugout water systems. Some are designed for drawing from the water source only. Others draw the water and force it through the rest of the distribution system. Some pumps are used for special purposes such as boosting pressure or supplying a special outlet. Therefore, it is important to select the proper type and size of pump for the application.

Select the proper type and size of pump for your application.

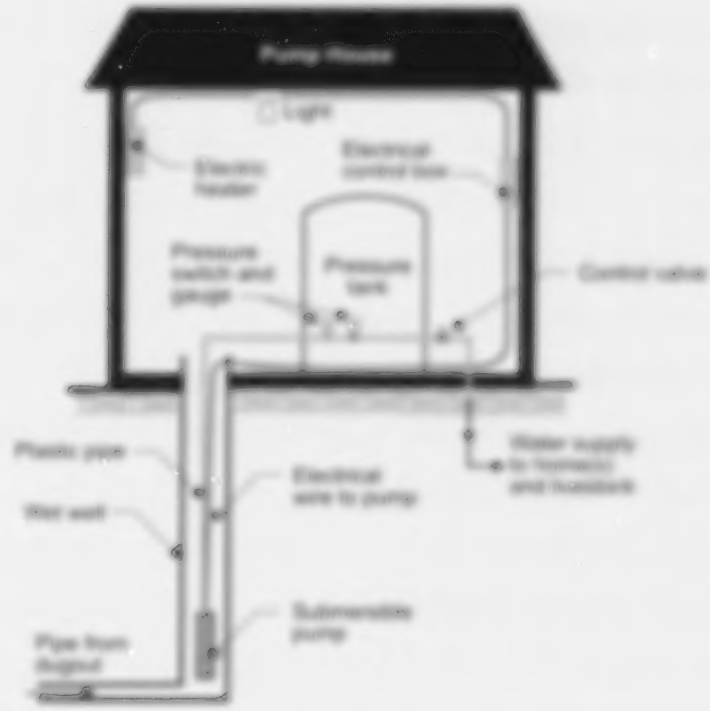
The most common pumps used for dugout supply systems are shallow well jet and submersible pumps. Shallow well jet pumps have a suction lift of approximately 20 vertical feet (7 m), including friction losses. Once water has been lifted to the pump, it can be pushed to higher elevations. Jet pumps can be installed away from the dugout in the basement of a house, heated shop, or pump house. Ensure that the suction line is adequately sized. Jet pumps require a larger intake pipe than submersible pumps but save the cost of running electrical power to the dugout. Jet pumps are not as efficient as submersible pumps and are more suited for supplying smaller volumes of water for rural residences.

A submersible pump can lift water hundreds of vertical feet. It operates like a shallow well pump but has a number of impellers or stages mounted close together on a shaft. Generally, because of the low lift required for dugout applications, a pump with six to ten stages or impellers will supply all the pressure required. The most common size of submersible pump is 4 inches (10 cm) in diameter. These pumps are available in 1/2, 3/4, and 1 horsepower motors and larger.

The pumps are placed in a wet well beside the dugout. Generally a small heated pump house is set over or beside the wet well to house the pressure tank, pressure switch, electrical controls, and any other dugout pumping or aeration equipment (Figure 5-4 Submersible Pump, Wet Well, and Pressure Tank).

A rural water system requires a pressure tank. Pressure tanks store water and maintain water pressure between specified limits. As the water in the tank rises, air is compressed until the upper limit or cut out point is reached and pumping stops. The compressed air in the tank acts like a spring. When the valve is opened, the compressed air in the tank forces water to flow into the system. Demands on the water supply cause the tank pressure to fall until the lower limit or cut in point is reached and the pump restarts. Without this buffer, the pump will start each time a small amount of water is drawn. Constant starting and stopping causes unnecessary wear on a pump. A larger pressure tank will save some wear on the pump from cycling. A 30 to 50 psi pressure switch is most common for farming operations. Variable rate pumps are also now commonly used to eliminate this concern.

Figure 3-4 Submersible Pump, Wet Well, and Pressure Tank



A small livestock pump house may house dugout pumping and sometimes irrigation equipment.

There are four types of pressure tanks:

- a plain galvanized steel tank
- a plain galvanized steel tank with floating sealer or disk
- a diaphragm tank, pre-charged with air
- a bladder tank, pre-charged with air.

For dugout applications, it is best to have a sealed air diaphragm or bladder tank for submersible pumps as shown in Figure 3-5 Sealed Air Diaphragm Pressure Tank.

Figure 2.2 Model for Oxygen-Pressure Test

Dugout Aeration Systems

As previously outlined in the Understanding Prairie Dugouts Module, Biology of a Dugout section, an important part of maintaining water quality is ensuring that the level of dissolved oxygen in the water stays high all year round.

Under natural conditions in a dugout, oxygen exchange with the environment is not sufficient. In summer, a layer of warm water forms on the surface. The layer of warm water floats above a layer of deeper, cooler water. The layer of cold water, having no contact with the atmosphere, becomes depleted of oxygen. Under low oxygen conditions, plant nutrients, metals, and swamp gases are released from the dugout sediments and held by the cold water layer.

To prevent low oxygen conditions, aerate your dugout continuously

In fall, air temperature and the surface waters of the dugout cool rapidly. When the surface of the dugout reaches the same temperature as the cooler, bottom layer, the dugout 'turns over'. This means that the water in the dugout is no longer stratified and wind mixing of all the dugout water occurs. Nutrients and unwanted compounds become evenly distributed throughout the water.

During winter, ice cover prevents the transfer of oxygen from the atmosphere to the water. When oxygen is depleted, microbial activity in the sediments again begins to release unwanted compounds. One of these compounds, hydrogen sulphide, produces the rotten-egg smell that often develops in small water bodies in late winter.

The ice melts in spring, the surface warms, and the water mixes completely, distributing the unwanted compounds throughout the water. Dissolved nutrients become readily available to plants and algae near the surface. As the air temperature increases, the cycle begins again.

In order to prevent this cycle of low oxygen conditions from developing, supplementary aeration is required. This adds oxygen to the water and ensures complete mixing of the water so that contact with the atmosphere is maximized. Research has shown that dugouts should be aerated 24 hours per day, year round.

Types of Aeration Systems

Many types of aeration systems have been tried over the years including electrical, wind-powered, and solar-powered systems. Where possible, electrical systems are always preferred, but for remote locations, other power sources are required. All systems have advantages and disadvantages.

Wind-powered systems can be effective in low-sunlight winter conditions but only in areas where winds are relatively constant. Solar systems are very portable and work best in hot sunny conditions coinciding well with peak demand for water. Producers should try to find options that suit their operations and their geographic area.

Some floating systems that churn up the water on the surface and introduce air into the water are available, but research indicates that these systems are not very practical or effective for prairie dugouts.

Select an aeration system that suits your operation and geographic area.

Components of an Aeration System

There are four components to an aeration system:

- power supply
- air compressor
- aeration line
- diffuser.

Power Supply

As with pumping systems, aeration can be powered by electricity, solar power, or wind. For dugouts stocked with fish, use an electrical type compressor, as it will provide a continuous supply of dissolved oxygen. This is crucial for fish survival in a dugout. Windmill type systems may not pump sufficient dissolved oxygen for fish survival during low wind conditions at night or during hot calm periods in summer.

Air Compressors

Bank-mounted windmills use a diaphragm-type pump that pushes air into an aeration hose that extends to the bottom of the dugout. Windmills are suitable for areas with good wind conditions and for remote sites where electrical power is too costly to install. However, they perform poorly on sites where winds are obstructed by hills or trees, water is deep (over 20 feet or 6m), or there are high concentrations of organic matter in the water.

The most common types of electrical compressors are the oil-less diaphragms or piston pumps. These compressors are quiet, relatively inexpensive to purchase and operate, and require little maintenance. When choosing a pump, make sure it is rated for continuous use. As a rule, a diaphragm-type compressor that pumps approximately one cubic foot per minute (**cfm**), for every million gallons of dugout water, is adequate. For best results, locate the compressor in a heated building or enclosed box to protect the motor, diaphragm, and electrical supply.

Aeration Lines

Aeration lines convey air from the pump to the dugout. For new dugouts, the aeration line should be buried with the water intake line. This will prevent damage from frost, ultraviolet light, ice, and animals.

Diffusers

Choose a diffuser that creates fine to medium-sized bubbles.

A diffuser is a device to release air into the water. Research has shown that the type of diffuser is very important. Diffusers that create fine to medium-sized bubbles are more efficient at circulating and aerating water than open-ended hoses that produce large bubbles. An open-ended hose requires three times the volume of air to saturate water with dissolved oxygen compared to an air stone or perforated hose. Proper location of the diffuser maintains oxygen levels from top to bottom, as shown in Figure 5-7 Aeration System. It is important to place the diffuser at the bottom of the deepest spot of the dugout. Recommended types of diffusers are:

- Figure 5-8 Airstone Diffuser
- Figure 5-9 Linear Diffuser
- Figure 5-10 Membrane Diffuser.

It is a good practice to attach a rope to the diffuser in order to be able to retrieve the diffuser for periodic inspection and maintenance.

Figure 5-7 Aeration System

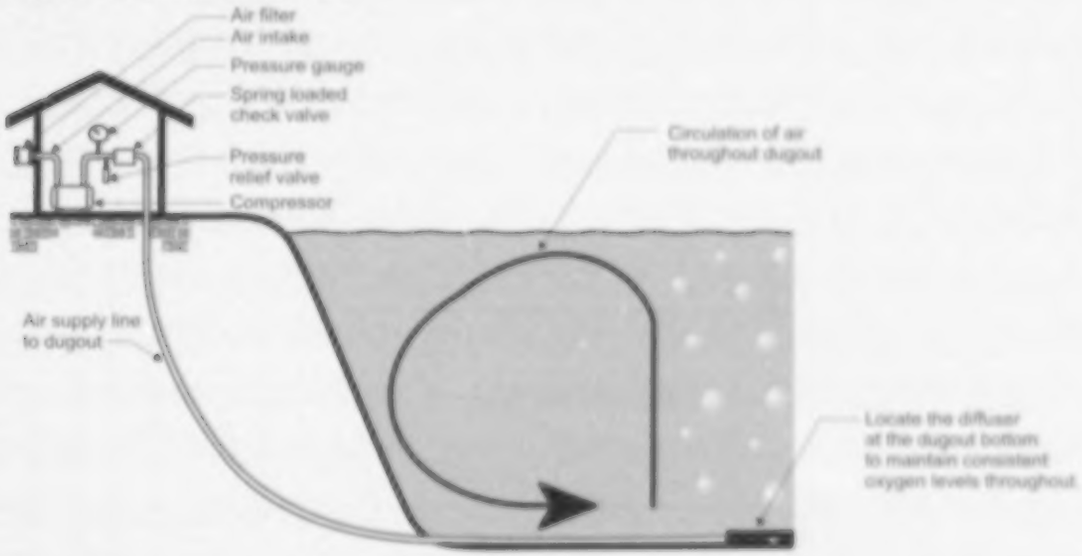

Air filter
Air intake
Pressure gauge
Spring loaded check valve
Pressure relief valve
Compressor
Circulation of air throughout dugout
Air supply line to dugout
Locate the diffuser at the dugout bottom to maintain consistent oxygen levels throughout

Figure 5-8
Airstone Diffuser

Figure 5-9
Linear Diffuser

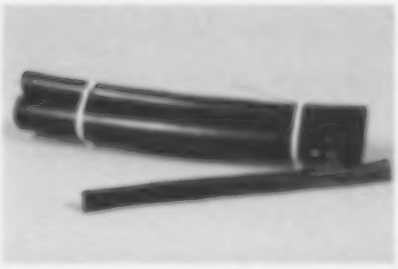


Figure 5-10
Membrane Diffuser

Safety

During winter, dugout aeration systems can result in open or weak areas in the dugout ice. These conditions can be very dangerous for young children, pets, and people sleepwalking at night. It is essential to educate your children about these hazards and post the area with highly visible warning signs and fluorescent snow fence around open water areas.

Remote Pasture Water Systems for Livestock

In the past, livestock were turned out to summer pasture and allowed to walk through and drink from any slough, creek, river, or lake available to them. In the winter, livestock either ate snow or holes were cut in the ice of these natural sources for them to drink. When these natural water sources were not available, dugouts were constructed.

Today, allowing livestock direct access to surface water sources is a concern to livestock producers and to other water users. The practice is also a concern for livestock safety and may lead to animal health concerns from poor water quality.

Livestock producers want to provide a safe, reliable supply of good quality water for their livestock and increase their management to better utilize their pastures for livestock production. Many producers are using remote water systems and applying the latest technology available for controlled livestock grazing and water feeding of livestock away from the foreground. Livestock producers, like other water users, want to do their part to protect both natural and constructed water sources from environmental damage and address herd health problems.

Problems with Direct Watering

Allowing livestock direct access to surface water sources has led to a number of environmental, herd health, and pasture utilization problems.

Environmental Problems

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Good Health Problems

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Pasture Water Systems

A variety of livestock watering methods are available to suit any type of pasture and location. The power options to move water to livestock include solar, wind, fuel, stream flow, mainline electricity, and gravity flow. Selecting the most appropriate one can be a challenge.

Establish a list of priorities for a pasture water option and use some of the natural advantages of the site and equipment.

Consider the following factors when you select a pasture water system:

- type and location of available water sources
- site locations and conditions (remote location, topography, riparian features)
- type of grazing system (intensive or extensive)
- number of livestock
- access to power source (mainline power, solar, wind, animals, etc.)
- pumping system (amount of lift, automated versus manual)
- flexibility and portability
- reliability and maintenance
- temporary or seasonal water storage
- need for frost protection (swath grazing or winter watering)
- cost/benefit and cost/animal
- personal preference.

Livestock Watering Alternatives

There are many viable alternatives to direct watering. These alternatives are described in some detail below.

Access Ramps

An access ramp is the minimum improvement that can be made to a water source (Figures 5-11a Cross-section View of Access Ramp and 5-11b Plan View of Access Ramp). Ramps are most appropriate for large herds of livestock in remote locations (i.e., rangeland pastures) where animals are seldom checked or moved. The reinforced ramps provide better footing for livestock drinking from dugouts, sloughs, and streams where soft soils (e.g., peat) exist

These ramps require a relatively low slope of 5 to 6 feet (1.5 - 1.8 m) for every foot (.3 m) of drop. Lay down a strip of crushed road gravel preferably with sizes from 1-inch (2.5 cm) diameter down to 10 to 15 per cent fines. The gravel layer should be a minimum of 1 foot (.3 m) thick. Start the gravel layer 10 to 15 feet (3 - 4.5 m) back from the water's edge and continue down to below the lowest water level of the dugout. Use a small caterpillar or 4-wheel drive tractor to spread and compact the gravel.

In soft soil conditions, place a plastic polygrid or geogrid under the gravel to provide added support. The material comes in 3 or 4 metre wide rolls and can be overlapped for wider ramps.

The water source is usually fenced off, so livestock can only drink from the access ramp. Some producers have found that fencing is not necessary because once the cattle have convenient access to water, with good footing, they will water almost exclusively from the ramp.

Figure 5-11a. Cross-section View of Access Ramp

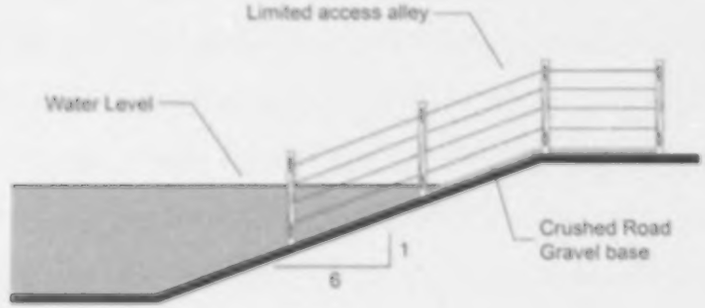
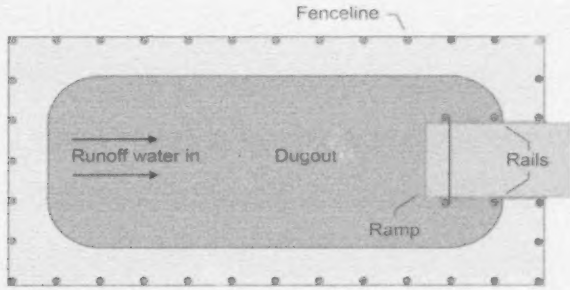


Figure 5-11b. Plan View of Access Ramp



Water Hauling

Although it may seem like a step back in time, water hauling can be a viable alternative. In intensive livestock grazing management, cattle are sometimes moved daily from pasture to pasture. Access to water is often the limiting factor. By utilizing an old truck with a main storage tank and an easily moved stock tank, the watering source, along with the cattle, can be continuously relocated throughout the pasture. The nutrients from the manure are more evenly distributed and are kept on the same field.

Water Storage

Alternative energy powered water pumping systems (including fuel, solar, and wind powered) all require water storage. The water storage tanks or reservoirs provide the necessary livestock water between pumping cycles. Most are raised above the stock tank to allow for the gravity flow of water. They are generally sized to hold a three- to seven-day supply of water for cattle. For sizing the water storage, use the following cattle water consumption rates for cattle on pasture:

- yearling steers or heifers – 8 gallons per day (36 L)
- cow-calf pairs – 12 gallons (55 L) per day.

These are average water consumption rates for cattle on pasture. On hot summer days, peak water consumption can reach 1.5 times these numbers.

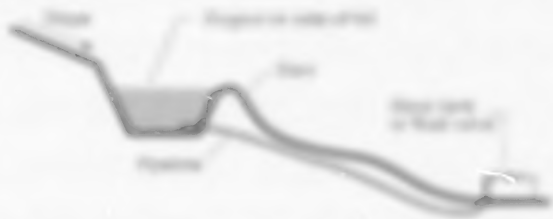
Water storages can be made from almost anything as long as they safely store water at a reasonable cost. The most common are plastic, fiberglass, concrete or metal tanks, elevated earthen reservoirs, grain bin rings, large rubber tires, or large stock watering tanks. The cost of water storages ranges from about 5 cents per gallon (1 cent per L) to well over $1.00 per gallon (23 cents per L). The lowest cost water storage (5 to 10 cents per gallon or 1 to 2 cents per L) is the elevated earthen reservoir (Figure 5-12 Elevated Earthen Reservoir with Woven Polyethylene Liner).

Figure 5-12 Elevated Earthen Reservoir with Woven Polyethylene Liner

Gravity-fed Systems

Gravity-fed systems are ideal systems on sloping pasture land where it is possible to locate a dugout or dam upslope from a watering site. A pipeline can then be run from the dugout downslope into a stock tank. As a rule, the water level in the dugout should be at least 5 feet (1.5 m) higher than the stock tank plus 1 foot (.3 m) additional height for every 100 feet (30 m) of pipeline to the stock tank as shown in Figure 5-13 Gravity-fed System.

Figure 5-13 Gravity-fed System

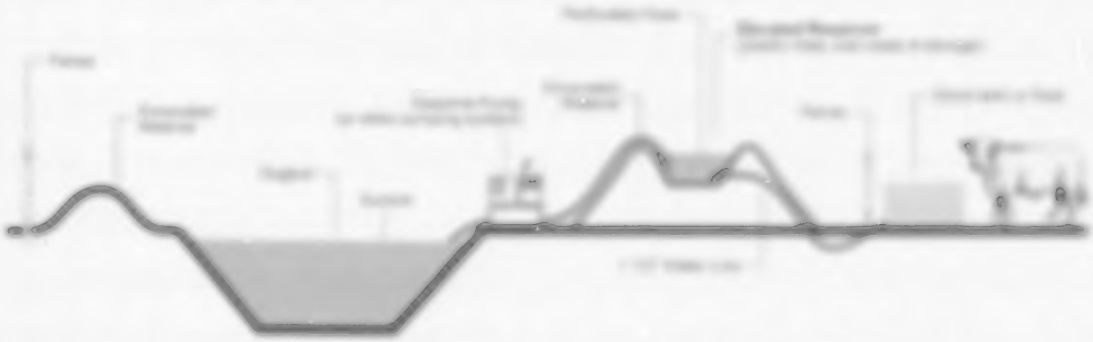


Gravity-fed systems can also be used for springs where there is sufficient elevation drop to the stock tank. On long, undulating and/or steep drops, take extra care to avoid leaks or air blockages.

Pumped Gravity Flow Reservoirs

These reservoirs are generally constructed by digging a small reservoir on top of the excavated dirt piles from a dugout (similar to Figure 5-12). A standard backhoe can construct these in a few hours. The reservoir is then lined with a woven polyethylene liner to prevent seepage and to keep the water clean. The reservoir bottom must be higher than the top of the stock tank. This approach will provide adequate gravity flow from the reservoir through the water line and float valve assembly and into the stock tank as shown in Figure 5-14 Pumped Gravity Flow Reservoirs.

Figure 5-14 Pumped Gravity Flow Reservoirs



Selecting the proper size water line and a high capacity, low-pressure float valve are also important to ensure adequate flow rates. Table 5-1 shows the dimensions and water volumes for a typical elevated earthen reservoir.

Table 2-1 Elevated Gasoline Reservoir Water Volume (U.S. Units)

Reservoir or Tank Capacity, gal. Typ.	Length x Width x Height Metric	Approximate Water Volume Displaced, Gallons
25 x 10	10 x 5 x 3	1,000
15 x 10	10 x 5 x 3	1,000
40 x 20	10 x 10 x 3	3,000
25 x 20	10 x 10 x 3	3,000
25 x 20	10 x 10 x 3	3,000
25 x 20	10 x 10 x 3	3,000

Vented Operated Position Pumps

Many positive pumps are commonly called lever pumps because valve operation is by a pushing lever with lever action as shown in Figure 2-13 Hose Pump. The pump provides a one way valve pumping action against a head of 100 psi or more with each stroke of the lever.

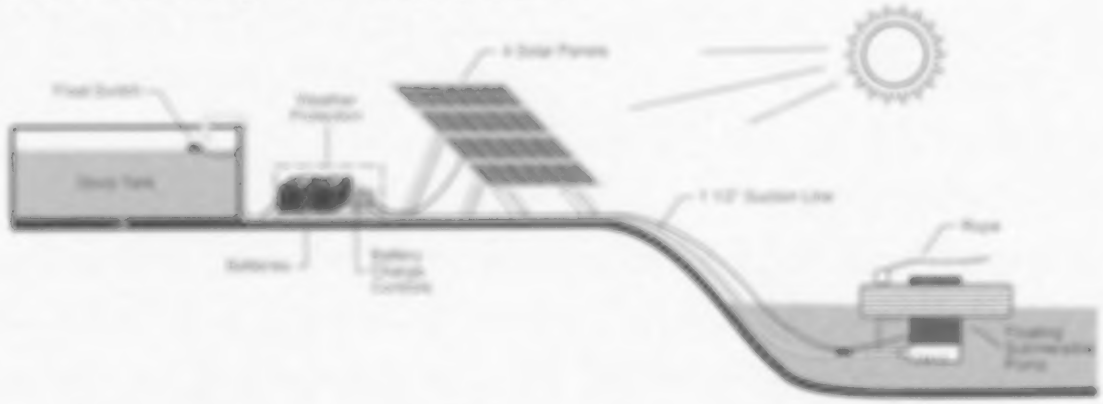
Many gas pumps, pump assemblies, and lever pumps commonly in use with the lever type pump that is operated by hand or foot. Some of the pumps are capable of delivering more than 30 gallons per minute. Capacities vary according to the size of the pump. The conventional pumps are the most common and are used with the lever or a handle to force the pump. Can also be fitted to gasoline or water drums for easy transfer. The diameter lever pump uses a piston pump and has been developed over 30 years. It has been used for many years by the diesel and truck. Whatever the purpose of the pump the lever is used to move the valve and allow or prevent the pump. Refer to Section 2-3 for pump flow rates.

Figure 2-13 Hose Pump

Solar-powered Pumping Systems

Solar systems are becoming more popular because of their reliability and low maintenance. They can be used to pump water from dugouts. An array of solar panels collect and convert sunshine into electrical energy, which can be used to pump water or be stored by rechargeable batteries as illustrated in Figure 5-16 Solar-powered Pumping System. Due to the variation in sunshine intensity, a minimum of three days or greater of water or battery storage is desirable.

Figure 5-16 Solar-powered Pumping System



Solar-powered systems are ideal for portable, stand-alone dugouts.

For the solar direct systems without batteries, it is important to match the solar panel's output (in watts) to the power requirements of the pump for maximum efficiency. For solar systems with batteries, it is important to select good quality deep cycle type batteries (e.g., recreation vehicle type). It is also important to install electrical controls that have both low and high voltage disconnects. These protect the battery from under or over charging conditions, which will drastically reduce battery life. Obviously, a sunny spot is desired for these systems, but also choose a location that is not in plain view and is sheltered from high winds.

Solar powered systems have the added advantage of pumping the most water on hot sunny days when cattle are drinking lots of water. Excess power can be used to energize an electric fence for the pasture. Although the initial costs of this system are somewhat higher than for others, they will last for many years. The portability of the solar pumping system is another advantage.

Wind-powered Pumping Systems

Windmills perform best in areas that have higher than average wind speeds, such as the southern parts of the Prairie Provinces. For central and northern areas of the prairies, where wind speeds are lower, consider adding additional water storage such as an elevated earthen reservoir.

Windmills can be used to pump from dugouts and wells. Place windmills on higher ground where they have good exposure to the wind, such as the excavated dirt pile from a dugout. Also, locate them away from trees as far as possible, at least 15 to 20 times the height of the trees as shown in Figure 5-17 Wind-powered Pumping System.

Figure 5-17 Wind-powered Pumping System

Windmills must be located on higher ground away from trees so they perform efficiently.

There are presently two windmills that can be used for both dugout water pumping and dugout aeration. The initial costs of the system are somewhat high, but most of the windmill systems are very reliable and will last for many years. A windmill system should have at least three days of water storage. Be prepared to use an alternate pumping method or haul water during prolonged calm periods.

Options for Winter Watering Livestock at Remote Locations

Although livestock prefer water, snow is an acceptable water source for mature cows and young cattle in good condition. For snow to be used as a water source, there must be an abundant supply, and it must be clean, unpacked, and with no crust so that it's easily accessible by livestock. Provide lactating cows with calves, as well as first and second calf heifers, with water to maintain body condition during the winter months.

In the last few years, more producers are installing winterized pasture water systems from dugouts and water wells to supply water to their livestock. The reasons for these systems include:

- extending the pasture grazing season and fall and winter swath grazing
- lack of water at the farmyard site
- winter feeding of cattle on pasture and cropland to reduce manure hauling costs
- providing increased flexibility for separating cattle at weaning and calving times
- preventing manure buildup in the calving areas
- reducing animal health problems associated with the above
- death losses due to drowning.

With the proper planning and design, almost all the traditional summer pasture water systems can be modified and used throughout the winter. To prevent freezing, you need to supply heat, reduce heat loss, or use a combination of the two. There are many options for winter watering including commercially available "earth-heated" waterers, super insulated "energy free" waterers and water troughs that rely on the heat stored in the water itself to keep it from freezing, and propane heated waterers. There are also continuous water flow-through systems to prevent freezing, frost-free animal operated nose pumps, and solar and wind powered pumping systems for winter use.

Each system has its place, and personal preference, reliability, livestock herd size, cost, remoteness, and the site location are all factors to consider when choosing an appropriate system. For remote dugout locations on the Prairies, watering systems must be durable and able to withstand temperatures that drop to - 40°C.

Most winter watering systems available on the market today have a common setup. The main components are an intake water line from the dugout, wet well, power source, and pump (see Figure 5-18 Watering Bowl with a Drain Back System).

The most common pumping systems currently being used during the winter are solar powered. The solar panels are used to charge batteries which supply electrical power for running a pump. Two basic design concepts prevent freezing – a drain back system or a well-insulated trough system. The basic components of a solar system itself are:

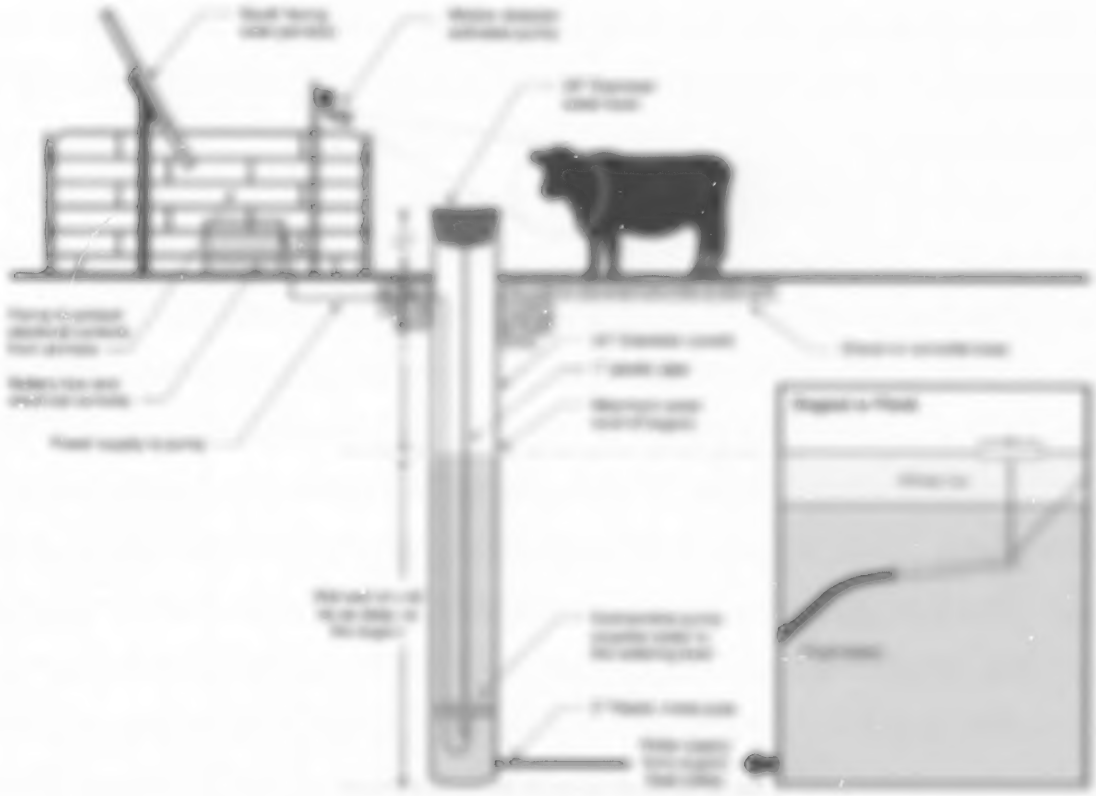
- solar panels
- deep cycle batteries
- battery charge controls
- pump
- a motion detector or float switch to start and stop the pump
- water lines
- a watering bowl or water trough
- other options including a wind turbine to supply additional power for the batteries during extended cloudy periods and an aerator to improve dugout water quality.

Watering Bowl with a Drain Back System to Prevent Freezing

This system is set up directly over the wet well beside the dugout and uses a motion sensor to activate the solar-powered pump. The motion sensor starts the pump when livestock approach the watering bowl to drink. Water is pumped into the bottom of a 25-inch (63.5 cm) diameter round watering bowl located on top of a 24-inch (60 cm) diameter culvert or wet well. The water level rises in the bowl to a set of overflow holes that return excess water back into the wet well. These holes are located near the top edge of the bowl to prevent overflow onto the ground. The pump will run as long as there is livestock motion within the range of the motion detector. To prevent the pump from starting and stopping, a delay is built in to allow the pump to continue running for a preset time. This delay allows the next animal to approach the watering bowl and get water before the pump shuts off. Water remaining in the bowl after the cattle have finished drinking drains back to the wet well through the bottom of the bowl so that no water remains in the bowl to freeze. Motion detection systems are adaptable to a variety of setup configurations as shown in Figure 5-18 Watering Bowl with a Drain Back System.

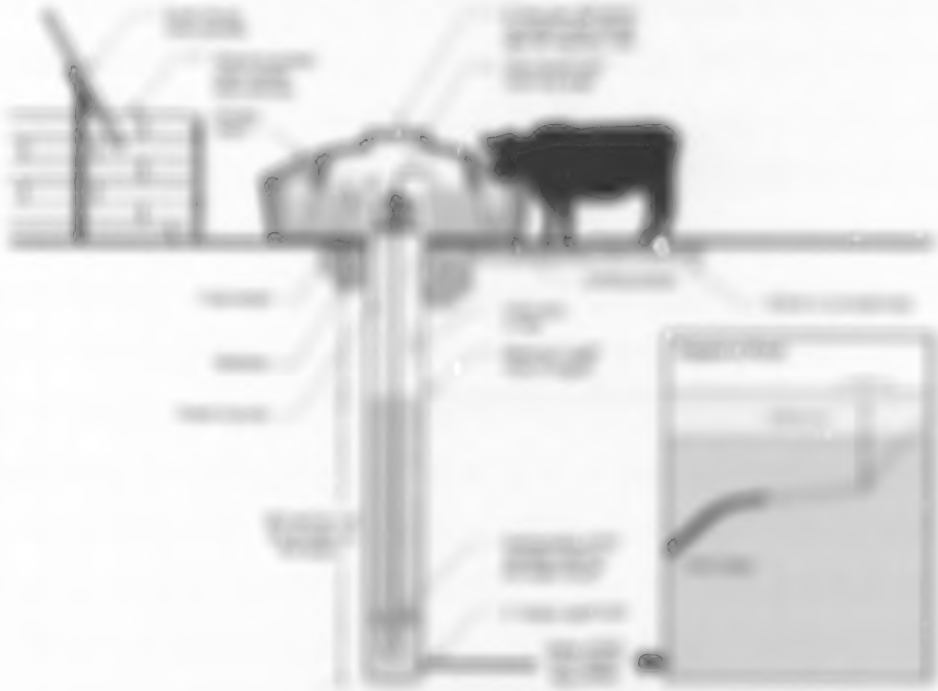
The ground level at the watering bowl site should be at least 7 feet (2.13 m) higher than the maximum water level of the dugout. This amount of soil cover will prevent frost penetration and freezing of the water in the wet well. Slope the site away to provide good drainage to ensure a dry, clean, safe watering site during mild thaw weather events.

Figure 3-16 Watering Bowl with a Drain Rock System



With Insulated Trough System vs. Previous Drawings

Figure 5-28 With Insulated Trough System



The Second Key Idea

Here is a short paragraph that explains the second key idea. It has a little room to breathe on the page.

Figure 11.2: The Second Key Idea

A closing paragraph that wraps up the section and points the reader toward what comes next.

Water Quality for Domestic and Human Drinking Water Supplies

Domestic and drinking water supplies have higher quality requirements than most other uses. Water that appears to be acceptable based on visual appearance, taste, odour, and colour may contain contaminants that affect human health. Risks can be chemical or microbiological. It should be remembered that water that has been successfully treated for human consumption might become re-contaminated and present real health risks. Re-contamination sometimes occurs in the distribution system.

On the other hand, water that is otherwise harmless may have such objectionable appearance, taste, and odour that it is unacceptable for household use.

Health Risks and Water Quality

On first appearance, water would appear to be a relatively simple liquid. It is, however, a powerful solvent that is capable of containing a very complex mixture of chemical substances. Water also provides a suitable medium in which a diverse range of microbiological organisms can exist. The presence of various chemical constituents and microscopic organisms in water may impact upon human health.

Microbiological Factors

Waterborne microbiological diseases are caused by bacteria, protozoa, and viruses.

There are three major groups of microbiological organisms that cause waterborne diseases:

- bacteria
- protozoa
- viruses.

Examples of each of these three groups of pathogenic organisms are given in Appendix 2, Water Quality Guide in Table 1, Causes and Symptoms of Some Waterborne Diseases, page 125, along with the symptoms of the resulting disease. All of the symptoms listed for a particular disease are not always observed. It should also be noted that this list is not exhaustive but contains examples of microscopic organisms that have been linked with waterborne diseases in the past.

In many cases, the association of a disease outbreak with exposure to contaminated water is not recognized. Many of the symptoms that are exhibited in some of these diseases are attributed to other factors such as the "flu" or food poisoning. As such, many cases related to waterborne disease are

never reported to health officials and therefore available statistical data are understated. The number of people contracting diseases from the consumption of contaminated drinking water is conservatively estimated to be between 900,000 and 3,000,000 each year in the United States.

In Canada, notifiable disease statistics are the responsibility of each province and considerable variation exists in the manner and completeness with which this information is collected. Consequently, the number of individuals affected by waterborne diseases is not known in Canada. If one assumes a similar rate of occurrence for waterborne diseases in Canada, between 90,000 and 300,000 Canadians may be affected annually by water contaminated with microbiological organisms.

In many cases where disease outbreaks have been linked to drinking water, the cause is never determined. In the U.S. from 1991 to 1998, the identity of the agent causing waterborne disease outbreaks was not determined in 40 per cent of these cases.

Bacteria

Most bacteria found in water do not cause diseases in humans. Types of bacteria that do cause disease are found in the intestinal tract of warm-blooded mammals, including humans. These bacteria are excreted in waste matter and may be carried into water supplies.

Seepage from septic tanks and sewage lagoons, plus runoff from livestock feedlots, pastures, and cropland to which manure has been applied may contain bacterial contaminants. Similarly, fecal matter may also be introduced from rodents, birds, and other wildlife. Surface water supplies are therefore highly susceptible to bacterial contamination.

Once bacteria have entered a water supply, they may continue to reproduce, thereby maintaining or even increasing the degree of contamination. Surface water supplies that are largely immobile, like dugouts, provide an excellent breeding ground for bacteria.

Floodwater usually contains high levels of bacteria.

Protozoa

Protozoa are a group of microscopic parasites that are frequently present in surface waters. Some protozoa, notably giardia and cryptosporidia, exist in the form of cysts. The protective covering of the cyst permits the parasite to survive in harsh environmental conditions. The cyst also protects the parasite against disinfectants such as chlorine. Once ingested, the parasite germinates and reproduces. Encysted parasites may subsequently be evacuated from the animal or human host through the feces.

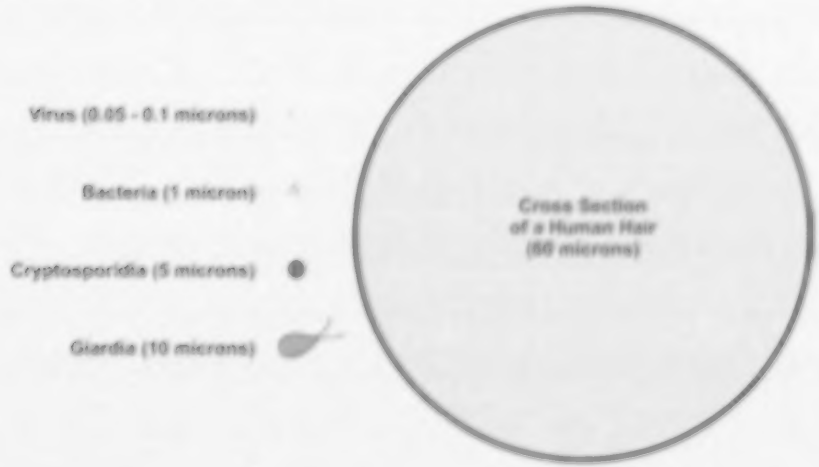
Cryptosporidia and giardia have been suggested as the causative agent in approximately 60 per cent of reported waterborne disease outbreaks in the U.S. between 1901 to 1968. Giardia are found in feces from humans, beavers, muskrats, and dogs. Cryptosporidia have been found mainly in fecal matter from cattle, sheep, and pigs. However, they have also been detected in the feces of humans and other mammals. Contamination of water supplies occurs when fecal matter containing the parasites is deposited or washed into the water.

Viruses

Relatively little is known regarding the incidence of diseases resulting from waterborne viruses. However, a number of different waterborne viral agents have been found in contaminated water supplies and linked to disease including hepatitis A, rotavirus, Norwalk agent, over 30 types of adenoviruses, and over 70 types of enteroviruses.

Figure 6-1 Relative Sizes of Pathogenic Organisms illustrates why pathogenic organisms are not visible to the human eye.

Figure 6-1 Relative Sizes of Pathogenic Organisms



Chemical Factors

There are a number of chemicals that can pose a human health risk. In some cases, these materials are naturally present in water through weathering and erosion. In other cases, human activities result in the introduction of these chemicals into water.

Chemicals that potentially have an adverse effect upon human health include naturally occurring minerals, metals, and toxins as well as a variety of synthetic, organic chemicals including many different types of pesticides. A list of the various chemicals, their sources, and their adverse health effects are listed in Appendix J, Water Quality Guide, in Table 2, Chemicals and Their Associated Risk to Human Health, page 126.

If you suspect that your water contains elevated levels of naturally occurring chemicals, or if you believe that your water has become contaminated, specific tests may be performed in a laboratory. There are numerous laboratories with a diverse range of analytical testing capabilities located in each province.

Aesthetics and Water Quality

Numerous chemical compounds and microbiological species affect the aesthetic quality of water. Certain compounds and species impart an objectionable taste or odour to water while others may cause staining or leave behind a residue or solid precipitate. These chemical agents and microbiological species are generally regarded as nuisances that typically do not pose a risk to human health. The most commonly encountered nuisance water problems are summarized in Appendix J, Water Quality Guide, Table 3, Chemical Agents and Microbiological Species Affecting Aesthetic Quality of Water, page 127. The sources of the nuisance impurities and organisms are listed along with the symptoms typically observed as a result of their presence in water. The presence of these impurities and organisms can be confirmed by laboratory tests. Once their presence has been determined, appropriate steps may be taken to eliminate or minimize the associated problems.

Standard Testing of Drinking Water

Testing for Coliforms

Pitfalls of Standard Water Testing Techniques

If a treated municipal drinking water supply is found free of coliform bacteria, it is generally assumed that the water treatment process is working adequately and that the distribution system is functioning properly. While most pathogenic bacteria and viruses are destroyed by disinfection, some organisms such as cryptosporidia and giardia may not be inactivated. Therefore, an acceptable result for coliform bacteria does not guarantee that all pathogenic organisms have been eliminated. Furthermore, an acceptable result for coliform bacteria on an untreated water supply such as a private well or dugout does not indicate anything regarding the presence or absence of protozoa or viruses.

Non-routine Testing of Drinking Water

While there are many laboratories that have the capability to test for coliform bacteria, total and fecal, as well as *E. coli*, relatively few have the capability to test for specific pathogens such as cryptosporidia, giardia, and various viruses. Many environment and health officials do not recommend routine monitoring of drinking water supplies for cryptosporidia and giardia due to the complex and expensive testing methods and the widespread occurrence of these protozoans in surface water. Instead of monitoring for protozoans, many agencies have preferred to focus on ensuring that adequate treatment procedures are in place for public and private water supplies and that best management practices are observed in the watershed.

Very few laboratories have the capability to test water routinely for viruses. This is mainly due to the lack of established testing procedures for many viral organisms. A second factor is that most laboratories perform microbiological testing on a very large number of samples. Testing all of these samples for even a small number of viruses would be practically impossible. This type of testing is normally only performed on the drinking water supplies of larger municipalities.

General Testing Recommendations

Test drinking water from a well or dugout at least twice a year, or more if there is a problem.

It is impossible to test a water sample for all known pathogens. It is also very expensive to test for a large number of different pathogens. Many health agencies have designated total coliforms as a standard indicator test to determine the bacteriological safety of drinking water. Test drinking water derived from a privately-operated source such as a well or dugout at least twice a year for bacterial safety. More frequent testing may be necessary if contamination is suspected or unexplained illness occurs. If continuing illness is observed, discontinue use of the water until a sample has been tested.

Water Treatment for Domestic Water Supplies

Water treatment is essential for all dugout water supplies used for household/drinking purposes.

***" The Rural Water Quality Information Tool"** provides an abundance of information on water quality, water sampling, testing, and treatment. The tool allows you to input your own water test results, and it then provides a detailed interpretation of the test results.*

The tool can be found on the Alberta Agriculture and Forestry website located at:

http://www.agric.gov.ab.ca

Click on the search Button and then in the search box type in ***" Rural Water Quality Information Tool"***.

If you are not going to adequately treat water, then haul good quality water for household purposes.

*Point-of-entry (**POE**) systems treat all the water as it enters the house.*

*Point-of-use (**POU**) devices treat small amounts of water at the tap.*

Water Treatment Systems

Water treatment of surface water for human drinking purposes is a complex and often difficult task. In this module, we discuss a basic description of methods and procedures of surface water treatment, but we are not able to provide exhaustive methods and details in the space available in this publication. Technicians that work in the water treatment industry require extensive education in order to understand the requisite knowledge. Hopefully this module will help you begin to understand some basic methods of surface-water treatment principles.

Water treatment involves a series of separate treatment processes in a standard sequence to produce a safe and aesthetically acceptable product. This sequence of treatment processes improves the quality of the water with each step, providing a multi-barrier, water treatment system. For surface water supplies, treatment must include steps to remove particulate and organic matter, followed by disinfection. Water treatment equipment can be expensive and always requires good maintenance practices to operate effectively over the long-term.

Surface runoff is usually high in particulate matter and plant nutrients. Algae and weed growth can be significant, particularly during the summer months, and dugouts generally have high levels of organic matter. While disinfection is an essential part of the water treatment process, high organic carbon levels can react with the disinfectant, producing potentially harmful by-products. The reduction of organic matter prior to disinfection is therefore an important step in the treatment process to produce biologically and chemically safe water.

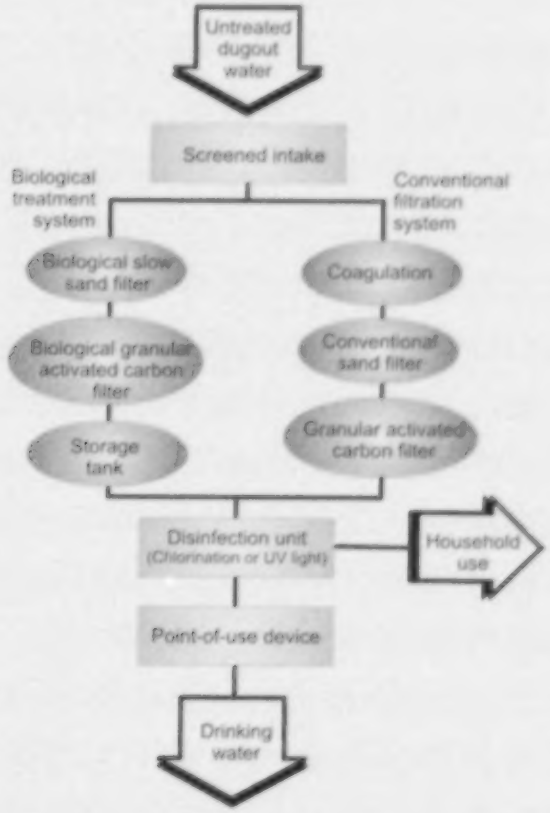
Traditionally for domestic use, dugout water treatment has consisted of either no treatment at all, or a combination of chlorination, rapid sand filtration, and/or granular activated carbon filtration. These types of treatments, by themselves, have not been successful at producing a high water quality product over the long term. Water produced from this type of treatment system should only be considered utility water and should not be consumed. While these processes can be effective to some extent, more effective pre-treatment is essential.

Figure 7-1 Surface Water Treatment Steps shows a schematic of two effective systems for treatment of dugout water as it enters the house. These systems are called 'point-of-entry' (**POE**) treatment systems. The first system includes chemical coagulation, filtration, and disinfection. The second system includes slow sand and biological activated carbon filtration followed by disinfection. In both cases, a final barrier such as a reverse osmosis (**RO**) membrane or distiller for drinking water, cooking water, and water for brushing teeth is added. This final barrier is called a "point-of-use" (**POU**) water treatment device. This type of treatment following point-of-entry treatment is referred to as "polishing". Polishing devices are designed for use on high quality treated water and are not capable of treating raw dugout water.

An effective in-house treatment system should be represented by one of the configurations in Figure 7-1. Other technologies, such as micro filtration, may be used to replace some of the processes identified in Figure 7-1 if they are properly designed and operated.

The treatment processes described can effectively treat most dugout water. Effective systems are designed to treat specific water problems. Therefore, dugout water should be tested before designing the system. Water problems that are not typical of dugouts may require system modifications.

Figure 7-1 Surface Water Treatment Steps



Steps in Water Treatment

The recommended system in Figure 7.1, consists of several consecutive steps. As previously discussed in Module 3 – Planning, the first step in a multi-barrier water treatment system is protection of the source water.

Screened Intake

A screened intake in the deposit is recommended as a pre-treatment to screen out larger particles, including algae, as well as reduce high turbidity.

Coagulation

Coagulation is a chemical process that can reduce turbidity, dissolved organic compounds, and colour. The chemicals most often used for coagulation are aluminium sulphate, ferric chloride, ferric sulphate, and polyaluminium chloride.

The coagulant causes small particles to join to form larger particles. During mixing, newer particles combine to form even larger particles called **floc**. The floc is visible to the naked eye and can be removed from the water through sedimentation or direct filtration.

Coagulation can be done in deposits or coagulation cells, or by using in-house coagulation systems. The two most common methods of coagulation for rural use are:

- constructing a small lined deposit or coagulation cell to treat a site to resolve unsafe supply of household water
- utilizing a commercial in-house coagulation system for continuous treatment of household water.

Coagulant chemicals must be dosed and mixed properly to achieve maximum benefits. On-farm coagulation has been experimentally successful, using simple treatment techniques for rural water supplies. Simple predictive tests have been developed for use on-site to determine the required dose rate.

For more information about coagulation, contact DPI-FSEW (339-8359) and ask for an agricultural water specialist.

Conventional Filtration

Biological Filtration

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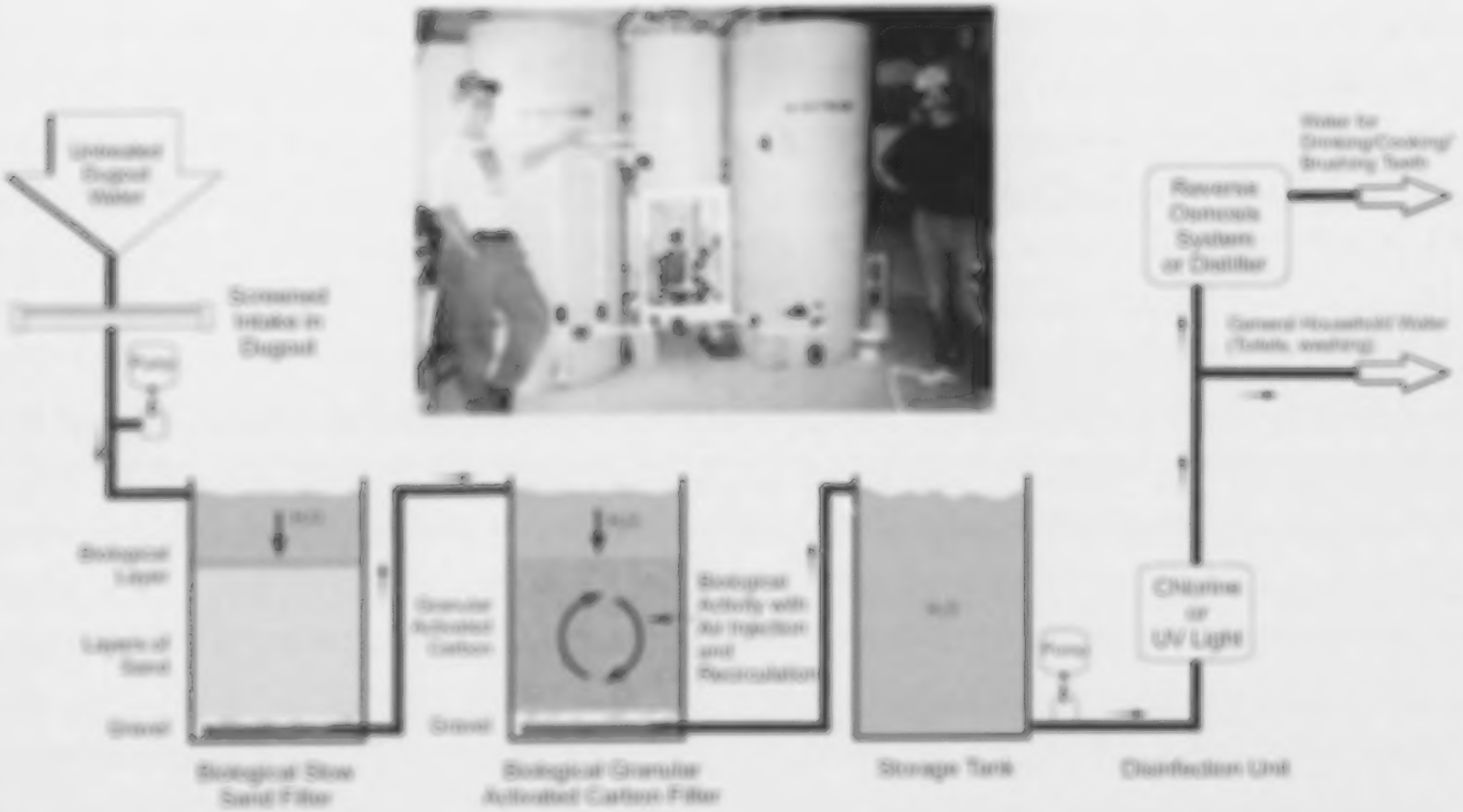
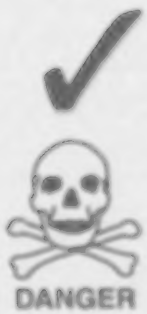
Figure 7.4 Biological Filtration System



Disinfection



You must disinfect dugout water for domestic use.

Disinfection is an essential step in the treatment of dugout water for domestic use. The purpose of disinfection is to reduce populations of pathogenic microorganisms to prevent the transmission of water borne diseases. This is different from sterilization, which completely destroys organisms. Common disinfectants include chlorine, chloramines, and ultraviolet (UV) light disinfection. It is important that the water has been successfully filtered prior to the disinfection step.

Organic material and mineral particles can shield microorganisms from the disinfectant, resulting in water that may be unsafe even after treatment. In addition, if chlorine is used as the disinfectant, and organic matter has not been reduced to low levels, potentially harmful chlorination by-products may form.

Contact time, pH, water temperature, organic concentration, and chlorine dose influence the effectiveness of chlorine disinfection.

Many rural residents prefer UV light disinfection, as it imparts no smell, taste, or odour to the water. UV light disinfection does not require chemical feed pumps and mixing tanks; however, it does not leave a disinfectant residual like chlorine for protection throughout the household distribution system. Wavelength, exposure time, water temperature, intensity of the light, and the presence of turbidity affect the effectiveness of UV light disinfection.

Polishing Treatment for Drinking Water

While it is recommended that the entire household water supply be disinfected to protect all water outlets in the home, a final barrier to supply safe drinking and cooking water is also recommended. This additional polishing step requires a distiller, or kitchen sink reverse osmosis (RO) unit. For additional detail on distillers and RO systems, see pages 92 – 95 in this module.

Maintenance of Treatment Systems

Operation and maintenance of in-house treatment systems is critical. If dugout owners are not prepared to invest the time and money required into treatment system maintenance, safe drinking water should be obtained elsewhere. Some treatment systems can be purchased with maintenance contracts to reduce the time and work associated with proper maintenance. A well-operated system will ensure that the water supply is safe and aesthetically pleasing. Regular monitoring of systems will give users confidence that the water they are using is safe. Maintenance should be tracked in a record book. If changes in quality are observed, corrective measures should be taken.

Be prepared to invest time and money into maintenance of treatment systems.

Conventional Pressure Sand or Multi-Media Filters

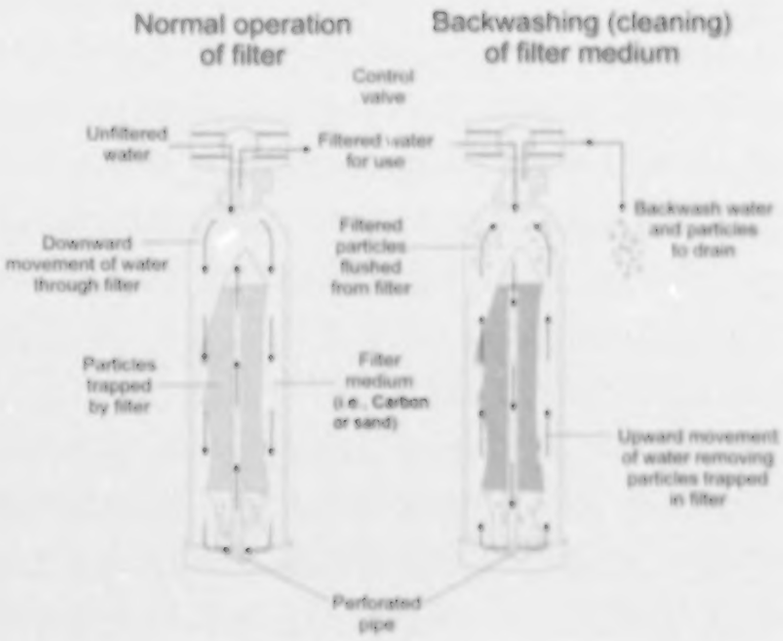
Pressure sand filters require regular backwashing as shown in Figure 7-4 Filter Backwashing. The backwash cycle can be set to start automatically. Backwashing frequency will depend on how much loading is placed on the filter by the feed water. In summer, when particulate loading is high, backwashing may be required as frequently as once a day. In winter, backwashing may only be required once every three to seven days. If water is pre-treated with continuous coagulation before the filter, the requirements for backwashing may be increased as unsettled floc from the coagulation process may clog the filter.

Organic matter will accumulate and plug pressure sand filters over time. For this reason, a manual backwash should be done at least twice annually, once in spring after snowmelt and once in fall, just before freeze-up. A manual backwash involves turning on the filter in backwash mode, unplugging the timer, and running a large quantity of water through the filter. Clean filtered water is preferred for backwashing. However, if raw water is used in this process, the wastewater should look as clear as the raw water. The backwash water should be inspected every 5 minutes for clarity. The manual backwash should be repeated until the backwash water is clean. If a filter is very dirty, backwashing may have to be repeated. If organic slime buildup is a problem, the filter can also be shock-chlorinated after the manual backwash. Filter media rarely require replacement unless the coarse filter gravel is displaced during overly aggressive backwashing.

Biological Sand Filters

Biological gravity sand filters may be designed for two types of maintenance regimes. The first regime involves backwashing the filter once every two to four weeks. The second involves replacement of the top layer of sand with new sand. Each spring and fall, the sand filter may require several cycles of backwashing to remove any accumulated material.

Figure 7-4 Filter Backwashing


Normal operation of filter
Backwashing (cleaning) of filter medium
Control valve
Unfiltered water
Filtered water for use
Backwash water and particles to drain
Downward movement of water through filter
Filtered particles flushed from filter
Particles trapped by filter
Filter medium (i.e., Carbon or sand)
Upward movement of water removing particles trapped in filter
Perforated pipe

Conventional Pressure Carbon Filters

Granular activated carbon filters are often referred to as GAC filters or activated carbon filters or even carbon filters. Pressure carbon (GAC) filters also require regular backwashing. If a sand filter is operating efficiently, the pressure carbon filter will require backwashing once every 3 to 14 days. It is always important to follow manufacturer's recommendations and adjust the frequency of backwashing to the type of water being treated. Manually backwashing for a longer time than the automated backwash may be useful if particulate matter has overloaded the filter. This should be done any time overloading is suspected.

A significant problem associated with carbon filters is carbon exhaustion. This occurs when the carbon simply cannot adsorb any more taste and odour compounds or dissolved matter. Carbon exhaustion is identifiable by treated water that is coloured or has a bad odour. The adsorption capacity of activated carbon in a pressure carbon filter will not last forever. For dugout water supplies, carbon exhaustion times can be highly variable, depending on water quality and the volume of water treated. Carbon media should be replaced at least twice a year, once in fall and once in spring. Full replacement, when organic matter has died off, provides better carbon filtration throughout the winter months. Spring carbon replacement, after spring runoff, provides for more effective filtration of water high in organic matter.

For dugout water supplies, replace the carbon media at least twice a year, once in the fall and once in the spring.

Granular activated carbon in the filters is often only effective for 2 to 3 months. Carbon can be an excellent surface for unwanted microorganisms to grow on. Backwashing may not remove them and pre-treatment with chlorine will not prevent them from growing. Carbon must be replaced regularly to guarantee high quality water.

Biological Granular Activated Carbon Filters

Biological, granular activated carbon filters should be backwashed every 4 months. After the backwash, the filter should be drained of treated water until the water runs clear. Some fine carbon particles will wash through the system and should be discarded. Periodic shock chlorination is not required on biological carbon filters. If carbon media degrade, they require replacement. Long-term experiments on biological carbon filters have shown that the filters have performed well for seven years without any need for carbon replacement. The keys to successful biological carbon filtration are:

- ensuring that the system is sized properly
- providing a continuous air supply
- backwashing frequently.

Raw water should not be chlorinated before passing through the filter, nor should it contain any components, such as copper, that may poison the organisms.

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[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

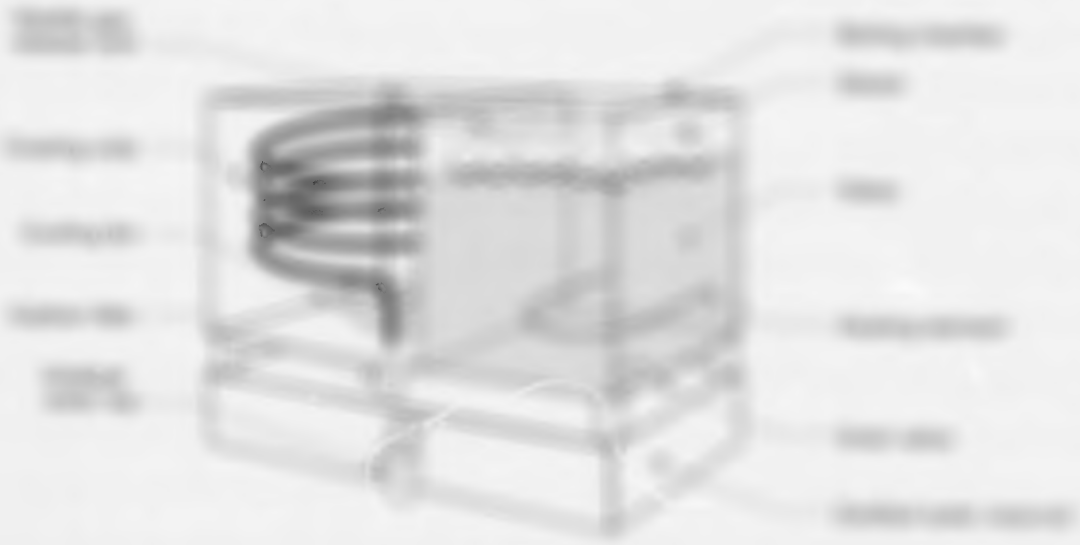
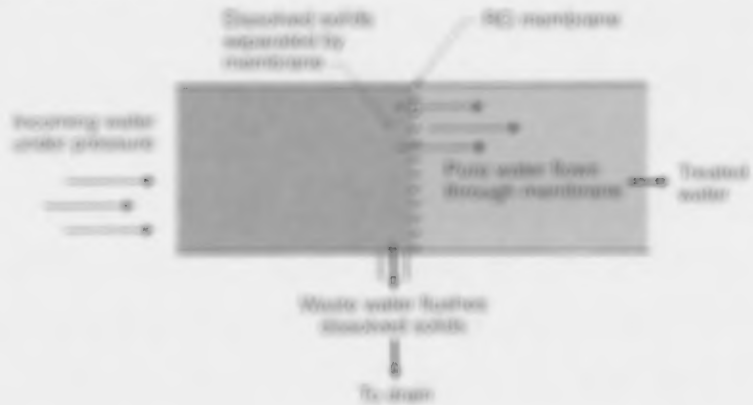


Figure 7-6 RO Treatment Process

Figure 7-7 RO Membrane



Do not shock chlorinate RO membranes since they only tolerate low levels of chlorine. RO membranes remove chlorine, so when testing for chlorine residual, draw the sample ahead of the RO membrane.

A granular activated carbon, polishing filter is often incorporated after the RO unit. This filter should be replaced at least four times per year. Granular activated carbon, polishing filters do not have to be discarded when replaced. They can be re-used once as the carbon filter in front of the RO unit.

Always follow manufacturer's recommendations for correct operation and maintenance procedures. The procedures must be suited to the specific treatment device.

Monitoring

Regular monitoring is the only way to determine how well a treatment system is performing. Keep a record of chlorine residuals, backwashing frequency adjustments, source water appearance, clarity, smell, and taste. Monitoring costs very little and increases confidence that the system is working well.

To judge the performance of a treatment system, test tap water for microbial safety at least twice per year. Critical times for water testing are:

- following spring runoff
- following any major runoff event
- mid-summer
- during maximum ice thickness.

Collect water in sterile bottles following the instructions of the lab performing the tests. Samples must be properly labeled and packaged, and delivered to the lab within 24 hours. Keep all results in a binder.

The following two Operation and Maintenance Schedule examples, Figures 7-8 Conventional Water Treatment System Schedule and 7-9 Biological Water Treatment System Schedule, show both the conventional treatment system and biological treatment system. Carefully review the examples to see the type of information recorded. Blank schedules for your use are located in the pocket at the back of the manual.

Equipment Certification

In Canada, water treatment equipment for private systems is not required to meet any standards or regulations. Furthermore, there is no Canadian certification mechanism for the effectiveness of water quality treatment.

Figure 7-8 Conventional Water Treatment System Schedule

Operation and Maintenance Schedule

Conventional Water Treatment System Operation and Maintenance Log

N.B. Chlorine always tested at kitchen sink tap

Date	Coagulation	Sand Filter	Carbon Filter	Chlorinator	Distiller
Feb 28	*Little floc visible*	*Backwash once/7 days*	*Backwash once/7 days*	*Tot. Cl = 0.5 mg/L*	*Cleaned Unit*
March	*Not tested; on holidays*				
April 2	*Adjusted dose for spring water*	*Manual backwash for 30 minutes and shock chlorinated filter; backwash once/4 days*	*Replace carbon media; backwash once/6 days*	*Tot. Cl = 0.0 mg/L increased to 0.5 mg/L*	*Cleaned unit; replaced elements*
April 9	*Settled floc OK*	*Backwash once/4 days*	*Backwash once/6 days*	*Tot. Cl = 0.2 mg/L; new batch and re-set to 0.5 mg/L*	*Working OK*
April 16	*Floc seems to be thickening*	*Backwash changed to once/3 days*	*Changed backwash to once/5 days*	*Tot. Cl = 0.1 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*
April 23	*More floc evident*	*Backwash changed to once/2 days*	*Changed backwash to once/4 days*	*Tot. Cl = 0.3 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*
April 30	*Floc is similar to last week*	*Backwash once/2 days*	*Backwash once/4 days*	*Tot. Cl = 0.6 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*
May 7	*Floc turning brownish*	*Backwash once/2 days*	*Backwash once/4 days*	*Tot. Cl = 1.0 mg/L Re-set to 0.5 mg/L*	*Working OK*
May 14	*Floc brownish, same density*	*Backwash once/2 days*	*Backwash once/4 days*	*Tot. Cl = 0.1 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*
May 21	*Thick floc (algae and sediment from rain)*	*Re-set backwash to once/day*	*Backwash once/4 days*	*Tot. Cl= 0.3 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*
May 28	*Floc is still thick*	*Backwash once/day*	*Changed backwash to once/3 days*	*Tot. Cl = 0.2 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*
June 7	*Floc is thinner*	*Re-set backwash to once/2 days*	*Re-set backwash to once/4 days*	*Tot. Cl = 0.7 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*

Figure 7-9 Biological Water Treatment System Schedule

Operation and Maintenance Schedule

Date	Slow Sand Filter	Biological Carbon Filter	Storage Tank	Ultraviolet Light	Reverse Osmosis
Feb. 28	*Air pump working*	*Air pump working*	*Air pump working*	*UV lamp is on*	*TDS is 350 mg/L (RO needs replacement)*
March	*On holidays; neighbours opened taps to flow 500 L of water weekly; air pump OK*			*Removed lamps; stained!*	
April 2	*Two manual backwashes with air and water and shock chlorinated filter*	*Three manual backwashes with air and water, filtered water was dirty, drained until clean*	*Shock chlorinated tank*	*Replace UV bulb and quartz sleeve*	*Replaced membrane and all filters (5 micron, both carbon filters); TDS is 50 mg/L*
April 9	*Air stone replaced; old air stone was plugged*	*Air stone was replaced*	*Air pump and air stone is OK*	*Farm power surge. UV on/off test performed to check UV, OK*	*TDS measured 45 mg/L*
April 16	*Air pump working*	*Air pump working*	*Air pump working*	*UV lamp OK*	*TDS measured 45 mg/L*
April 23	*Air pump OK*	*Air pump OK*	*Air pump OK*	*UV quartz sleeve cleaned*	*TDS measured 53 mg/L*
April 30	*Manual air and water backwash*	*Air pump OK*	*Air pump OK*	*Replaced UV ballast (damaged by power surge)*	*TDS measured 55 mg/L*
May 7	*Air pump OK*	*Air pump OK*	*Air pump OK*	*UV lamp OK*	*TDS measured 150 mg/L ?? calibrated meter, TDS 65 mg/L*
May 14	*Dirty water but filter working OK*	*Filter OK, air supply OK*	*Water still OK and air system working*	*UV lamp OK*	*TDS measured 57 mg/L*
May 21	*Filter starting to plug, so performed mini-backwash*	*Flow rate slowing down*	*Air system OK*	*UV on/off self-test performed*	*TDS measured 70 mg/L*
May 28	*Manual air and water backwash*	*Filter flow OK after sand backwashed*	*Air system OK*	*UV lamp indicator OK*	*TDS measured 60 mg/L*
June 7	*Air pump working*	*Air pump working, stone OK, circulation seems fine*	*Air system OK*	*UV quartz sleeve dirty; cleaned sleeve*	*Replaced plugged 5 micron filter TDS measured 55 mg/L*

Although private treatment systems are not regulated in the United States and Canada, the National Sanitation Foundation International (NSF International) does certify small treatment devices if the manufacturer is willing to apply and pay for the third party evaluation. Try to find equipment that merits certification by NSF International to ensure that equipment performance has been validated against accepted standards. Be aware, however, that the test was probably not performed using water that is as challenging to treat as dugout water.

Devices may also be registered with the United States Environmental Protection Agency (USEPA). This registration means the equipment has been tested to ensure the device will not give off contaminants that may harm the consumer. The USEPA does not test equipment performance.

Most importantly, work with a dependable water treatment company.

In 1999, Health Canada conducted the "Survey of Drinking Water Treatment Devices Available on the Canadian Retail Market". The survey covered seventeen cities across Canada including seven cities on the Prairies. The treatment devices studied included softeners, distillers, reverse osmosis systems, filtration systems, microbial purifiers, and UV systems. About half the devices surveyed were filtration systems, and about one-quarter were reverse osmosis systems. The devices were divided into three groups:

Try to use water treatment equipment that has been certified by NSF International.

- treatment devices for deodorizing water contaminated by microorganisms
- treatment devices for improving taste, odour, and appearance
- treatment devices for removing chemical contaminants

Health Canada Survey of Treatment Devices	
Models surveyed	318
Certified	38.0%
Uncertified	62.0%
Not NSF, but bearing name/logo	4.0%

The survey indicated that only one-third of the devices visibly tested were tested and certified by professional testing agencies such as NSF, Canadian Standards Association (CSA), or Underwriters Laboratories (UL). This leaves many questions unanswered as to the effectiveness and reliability of such devices in the treatment of dugout water.

Dugout Management

Figure 6-4 Dugout Maintenance Schedule

Dugout Maintenance Schedule

Year: 2008 - 2009 Dugout No: 1 Legal Land Description: NW 36-50-30-W4

Season	Date	Water Level	Comments (runoff, water quality, treatment, and maintenance)
Spring	March 25	4 ft. from full	- very little runoff, only added 2 ft. of water - increase in sediment in water - checked aeration pump
Summer	June 15	5 ft. from full	- water clarity decreased because of cyanobacteria growth - treated dugout with 4 litres of copper algicide to control cyanobacteria
	July 17	4 ft. from full	- put treated water wash around dugout edge with 1/2 litre of Reward (diquat)
	Aug 12	7 ft. from full	- water clarity decreased - re-treated for cyanobacteria with 4 litres of copper algicide
Fall	Oct 5	7.5 ft. from full	- approximately a 10 ft. depth of water left in dugout which will be adequate for winter use - pulled floating intake to bank and cleaned perforations - thoroughly checked dugout aeration pump diaphragm, and checked valves in preparation for winter - treated runoff control gate open and clean in preparation for next spring's runoff
Winter	Jan 15	10 ft. from full	- about a 5 ft. depth of water below ice - checked aeration pump
	Mar 1	11.5 ft. from full	- open runoff control gate prior to spring runoff

Summary of comments for the year and proposed improvements/changes

- Water levels were very low because of the lack of spring runoff and high evaporation losses.
- Try to increase runoff into dugout with additional snow fencing and make plans for new dedicated.
- Need to clean air diffuser as it seems to be restricting air flow into the dugout.

Dugout Management Practices

There are a great number of dugout management practices. Many are known to be highly effective, while others are still in the experimental stages. Some techniques do not require special or highly processed products or services or a high level of knowledge. Other treatments involve chemicals available in commercial products. This module outlines some of these practices, including their strengths and weaknesses.

Established Practices

The practices presented in this module are well-established methods of greatly improving dugout water quality.

Continuous Aeration

Continuous injection of supplementary oxygen is the single most effective practice for maintaining and improving water quality. Aeration is discussed further on page 52 in Module 5 – Operating Systems, Dugout Aeration Systems.

Floating Intake

Research shows that water in the top four or five feet of a dugout is of higher quality than water at the bottom and edges. The reason for this difference in quality is that the algae and plants that grow in dugouts eventually die and decay at the bottom and edges, resulting in black, smelly water conditions. Floating intakes draw better quality water from near the dugout water surface.

Sediment Removal

Excavation of accumulated sediment from a dugout, every five to ten years, is an effective technique for improving water quality and extending the life of a dugout. Unfortunately, it is costly, and in some cases excavation may exceed the cost of new dugout construction. Make careful cost estimates prior to deciding to clean out a dugout. Where two or more dugouts exist, divert all runoff away from the dugout to be excavated. Let the dugout dry up during summer, and excavate the sediment in early fall. Where only one dugout exists, the only way to excavate sediment under water is with a dragline or hydraulic backhoe. After excavation under water, expect the water to have high turbidity for up to several weeks or perhaps months. One option might be to pump the water to another location while the dugout is cleaned out and then pump the water back in.

Vegetation Control

Routine maintenance of the area around a dugout is important for maintaining water quality. Grassed buffers and runways surrounding dugouts should be mowed regularly. This prevents long grass from lying down and becoming ineffective as a sediment trap. Proper setback of shelterbelts ensures that the amount of fallen leaves entering the water is at a minimum. Steep end-slopes reduce the amount of emergent plants that can grow in the dugout. If possible, aquatic plants should be removed from the dugout before they die and decompose. Shrubs and trees will take root on the banks of the dugout. Left alone, they can grow quite large and contribute significant amounts of vegetation to the water in the fall. Annual cutting and removing of willows and volunteer saplings every fall can make a significant contribution to protecting dugout water.

Removal of Animals

Animals such as salamanders, also called mud puppies, and muskrats can create problems in a dugout by burrowing, house building, and foraging for plant roots. This disturbs the sediments and keeps the water constantly turbid. The most effective way to remove muskrats is through trapping or hunting. Specially designed fencing can be used to keep them out in the first place.

Copper Sulphate

Copper sulphate, also known as **bluestone**, is perhaps the most common chemical that was historically used to treat dugouts as shown in Figure 8-2 Bluestone Treatment. It is also the least understood. Copper is an essential element for both plants and animals, but at high concentrations, it can be toxic. All herbicides and pesticides are regulated in Canada by the Canada Pest Management Regulatory Agency and must be licensed for use. This includes any products that are used to treat dugouts. Various companies have registered copper sulphate (products) with the Canada Pest Management Regulatory Agency (CPMRA) in the past but have allowed the 5 year licences to expire; therefore it is important to check with CPMRA to determine which products are currently legal to sell in Canada. Most licensed products that have copper in their ingredients come in a liquid form. It is important to read and follow the directions of a licensed product to avoid environmental contamination and maximize effectiveness. Copper treatments can be very effective at controlling cyanobacteria. However, copper treatments are most effective when done in early summer before large populations develop.

Don't overdose! *Copper is not effective on green algae!*

Copper may also kill beneficial organisms, like zooplankton, which feed on some algae species. Overuse and repeated treatments can also cause a buildup of copper in the sediments of a dugout. This can harm or kill beneficial organisms and disrupt the normal biology of the dugout. In fact, a single overdose can also cause a man-made green algae bloom.

Health Canada recommends that the concentration of copper in drinking water for humans not exceed 1 mg/L copper. However, this is far below what would be a toxic level.

Copper treatments should therefore be done very selectively. It is not reasonable to expect dugouts to be completely free of green or brown algae, nor free of aquatic plants. The primary target organism of a copper treatment is cyanobacteria. If copper is applied during an algae bloom, there may be an immediate release of large quantities of toxin. Because of the toxins produced, it is recommended that you wait a minimum of 14 days before the water is used for human or animal consumption. This should allow toxin levels to dissipate. Continuous diffused aeration during this period may also help degrade toxins.

Figure 8-2 Bluestone Treatment

Copper is found in a variety of products. The active ingredient is always the copper element (Cu) itself. Contact the Canada Pest Management Regulatory Agency for the copper products currently registered for the control of algae in dugouts.

More information on copper products and procedures for treating dugouts is provided on page 128 in Appendix 3 Using Copper Products to Control Cyanobacteria.

Figure 6-3 Coagulation Cell

The coagulation process is outlined in Module 7 - Water Treatment for Domestic Water Supplies.

Coagulation

As opposed to treating the entire dugout, it is more economical to treat the small volume of water required for high-quality use in a specially constructed treatment cell, separate from the dugout as shown in Figure 6-3 Coagulation Cell. However, coagulation chemicals have successfully treated entire dugouts and have reproduced flood affected flushed dugouts. The addition of powdered activated carbon has proven to be helpful for increased removal of dissolved organic matter, taste, and odour compounds. If a dugout is coagulated regularly, chemical residues should be monitored.

Herbicides

Some herbicides are registered for use by the Canada Pest Management Regulatory Agency to control aquatic weeds and algae. These compounds may only be used on privately owned reservoirs where water does not flow into other water bodies, as shown in Figure 6-4 Herbicide Treatment. Always follow label directions, and use safe handling practices to protect yourself from the product. In order to calculate the proper dosage, you must accurately estimate the existing volume of water in the dugout to be treated.

Figure 6.4 Skateboarding Environment

Collaboration

[illegible]

Progress Controls

[illegible]

Diagram of the Sheet / Sheet Layout
with Sheet Number and Sheet Name
and Sheet Size

Disinfectants

Disinfectants are chemicals containing concentrated oxidants, such as chlorine, hydrogen peroxide, and ozone. They are effective at killing microorganisms when:

- the water is clean enough
- the dosage is strong enough
- the contact time is long enough.

However, disinfectants are non-selective and will kill off many beneficial organisms. Disinfectants can also create by-products that are potentially harmful to humans and should not be used in dugouts. Accordingly, they are not registered for use in dugouts.

Disinfectants are not registered for use in dugouts.

Plants

Plants have been used experimentally to improve water quality. Some species of aquatic plants may improve summer water quality by taking up nitrogen and phosphorus. With the fertility of the water reduced, the growth of unwanted algae species may be suppressed. Rooted plants such as cattails can serve this purpose. However, in order to maintain the water quality, the plants must be removed in the fall. If not removed, the plants will eventually die off, and plant nutrients will be returned to the water.

Because bottom-rooted plants can be difficult to harvest, there is interest in using floating plants to improve water quality. Duckweed is a floating, native plant that is able to take up large amounts of phosphorus from water but must be constantly harvested and removed from the dugout. It only survives in relatively sheltered locations and often blows to the downwind side of a water body. Water hyacinth is a floating, tropical plant that has only been used experimentally on Canadian dugouts to reduce algae problems. Both duckweed and water hyacinth can be harvested using a floating boom, as shown in the Figure 5-6 Harvesting Duckweed.

Figure 8-6 Harvesting Duckweed

Harvesting can be accomplished by dragging a floating timber boom across the dugout to the opposite shore and removing the plants.

Fish

Fish are sometimes added to dugouts to improve water quality by eating aquatic plants. However, they may often compound dugout, water quality problems by increasing turbidity, increasing dissolved nutrients, and making it difficult to use other chemical methods of algae and plant control.

For the same reasons that plants should be removed from a dugout, fish should be harvested before they die and decompose. Grass carp or *Tilapia* are effective at removing plants in dugouts but because of concern about the possibility of escape into the wild, their use is not permitted in some provinces. Check with provincial authorities before considering the addition of fish to a dugout. Some fish, notably rainbow trout, can actually degrade water quality by eating phytoplankton and adding excrement to the water.

Miscellaneous Biological and Chemical Products

There are a number of products now available on the market that are advertised as having the ability to improve water quality. Many of these products have been developed for non-consumptive ponds such as golf courses, ornamental ponds, and zoo ponds. The range of products includes various type of bacteria and chemical toxins. Check for registration with the Canada Pest Management Regulatory Agency of Health Canada and, if registered, check the registration/certification information for any specified water use limitations.

Many of these products are **not** registered by the Canada Pest Management Regulatory Agency for application to dugouts or farm ponds used for consumptive purposes and, therefore, should not be used. Until research proves the effectiveness and safety of these chemicals in dugouts, their use is not recommended.

Trouble Shooting Guide for Dugout Problems

Dugout problems fall into two broad categories: water quantity and water quality. Problems can result from the watershed; the dugout location, design, and construction; the systems and equipment for pumping, aeration, and treatment; as well as management practices. This module is designed to identify the source of a problem and provide suggestions for correction. The troubleshooting guide starts by identifying typical symptoms of water quantity or quality problems. It systematically lists possible causes, identification features, suggestions for corrective action, and references for further information within the manual.

Symptom: I Low Dugout Water Levels

Possible Causes	What to Check For	How to Correct (Options)	For More Information See Section (So)
Inadequate watershed	• observe or measure the area contributing water to the dugout during runoff events	• enhance snow trapping in the watershed with shelterbelts, snow fences or crop stubble • pump water to fill dugout • develop another water source	• Watershed Runoff Potential and Dugout Sizing, page 19 • Appendix 4 Contacts and References, page 130 • Planning Farm Water Supplies, page 18
Drought	• what are normal snow and rainfall amounts for your area? Information available from Environment Canada	• snow trapping • pump water from another source • increase water storage • develop another water source (back up) for drought proofing purposes	• Watershed Runoff Potential and Dugout Sizing, page 19
Dugout too small	• compare annual water use and ice and evaporation losses with dugout size recommended • consider any future expansion, etc. • steady drop in water levels	• increase dugout size and/or add another source	• Watershed Runoff Potential and Dugout Sizing, page 19
Seepage from dugout	• sand lenses or layers of silts and fractured clay	• use dugout sealing techniques • relocate dugout to suitable soil condition	• Large Scale Sealing Methods and Materials, pages 33–37
Soil deposeling in dugout	• soil erosion in watershed or watercourses draining to dugout	• use soil erosion techniques such as a grass cover and gated culvert inlets to the dugout to prevent sedimentation • remove sediment from dugout with a large tractrice or dragline • use a 2 dugout system, one for a settling pond and the second for use	• Water Quality and Watershed Management, pages 29–32 • Dugout Design, page 53–54 • Sediment Removal, page 102 • Sedimentation Dugouts, page 34

Possible Causes	What to Check For	Step to Correct Problem(s)	For More Information See Section No.
• [illegible] shortages of drainage	• [illegible] drainage; heavy storming or [illegible] shortages in water courses • [illegible] drainage or [illegible] reducing runoff to [illegible]	• [illegible] to remove snow items to verify that to return water runoff • [illegible] appropriate agencies responsible for erosion control and or watercourse drainage • [illegible] provincial government agencies responsible for drainage approvals	• [illegible] [illegible] [illegible], page [illegible] • [illegible] [illegible] [illegible], page [illegible]

Symptom 2 Disease or Natural Variance / Lack of Hy Supply / Contamination

Possible Causes	What to Check For	Step to Correct Problem(s)	For More Information See Section No.
Water Contamination	• identify potential sources e.g. contamination of the [illegible] and [illegible] [illegible] as [illegible] and groundwater	• [illegible] using the water source, and ensure local health unit, doctor or veterinarian for their assistance • remove the source of contamination wherever possible and replace good source if [illegible] with finding [illegible] • seek advice from water treatment specialists • provide another source of uncontaminated water or install appropriate water treatment equipment • Install filtration and disinfection equipment • install [illegible] treatment equipment such as R.O., U. water sterilizer • install [illegible] or haul in water for household use, and drinking	• Health Units and Water Quality, pages [illegible] • Rainwater Testing of Drinking Water, pages [illegible] • Health Units and Water Quality, pages [illegible] • Water Systems, pages [illegible] • Steps in Water Treatment, pages [illegible] • Steps in Water Treatment, pages [illegible] • Steps in Water Treatment, pages [illegible] • Steps in Water Treatment, pages [illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

Possible Causes	What to Check For	How to Correct (Options)	For More Information See Section On:
Depletion of dissolved oxygen levels in dugout water (winter)	• dugout aeration equipment not installed or working properly • snow cover on dugout reducing sunlight and oxygen produced by growing plants	• check and maintain dugout aeration equipment • where feasible carefully clean snow-cover from a portion of dugout surface	• Dugout Aeration Systems, pages 52–56
Black smelly water after Home Treatment System only	• filter system fouled with organic material and organic sediments in pressure tank and/or hot water	• clean or replace filter medium • ensure adequate disinfection of water	• Steps in Water Treatment, pages 64–68
Bottom dugout water entering from damaged intake pipe	• damaged intake pipe	• hire a diver to repair water intake pipe	• Steps in Water Treatment, pages 64–68

Symptom 4 Dirty Dugout Water

Possible Causes	*What to Check For*	*How to Correct (Options)*	*For More Information See Section On:*
Soil erosion of watershed and watercourses	• soil erosion • recent runoff event • suspended clay particles that will not settle	• employ soil erosion techniques and gated inlet • use a two dugout system • use coagulants in dugout to clear water	• Dugout Design, pages 32–34. • Water Quality and Watershed Management, pages 26–28. • Sedimentation Dugout, page 34. • Coagulation, page 105.
Erosion in dugout	• soil erosion by wave action	• protect eroded dugout banks with erosion prevention materials like filter cloth, plastic, or riprap • install water treatment system including coagulants and sand filter	• Dugout Construction, pages 35–41. • Steps in Water Treatment, pages 84–88.
Muskrats, ducks, mud-puppies	• abundance of cattails and tunnels into dugout banks • floating cattails	• control cattails and remove muskrats by trapping, etc.	• Dugout Management Practices, pages 102–110.
Contaminated runoff	• test water for bacteria, chemicals, and pesticides	• remove contaminants and/or cause from watershed • divert any contaminated runoff around dugout • install water treatment equipment	• Water Quality and Watershed Management, pages 26–28. • Steps in Water Treatment, pages 84–88.
Human activity	• swimming	• eliminate swimming	

Symptom 5 Discoloured Water and Staining

Possible Causes	*What to Check For*	*How to Correct (Options)*	*For More Information See Section On:*
Iron in Water	• brown to rusty coloured stains on clothes and plumbing fixtures	• install dugout aeration system and/or iron removal treatment equipment if required • replace gravel trench filters with floating water intakes	• Dugout Aeration Systems, pages 52–56. • Steps in Water Treatment, pages 84–88. • Intake Systems, pages 44–47.
Organic Matter in Water	• sloughy conditions around dugout	• prevent flooding and slough conditions • re-locate dugout	
	• staining • abundance of organic material and peat soil in watershed or dugout area	• coagulation treatment • re-locate dugout • cover organic material around the dugout with clay soil and grass cover	
	• decomposing plants and animals • excessive plant and algal growth in dugout	• install aeration equipment • use gated inlet to allow clear water into dugout • control nutrients coming into dugout which encourage plant and algal growth	• Dugout Aeration, pages 52–56. • Dugout Design, pages 32–34. • Water Quality and Watershed Management, pages 26–28.
	• green to yellow colour (dissolved or particulate organic colour)	• control algae and plant growth with a combination of biological, physical and chemical methods • install aeration equipment	• Dugout Management Practices, pages 102–110.
	• shallow dugout with flat slopes	• steepen dugout slopes and deepen dugout	• Dugout Construction, pages 35–41.
	• watershed/watercourse vegetation containing clover etc. • excessive dosages of chemicals including copper sulphate for algal control resulting in man-made blooms of green algae	• avoid planting vegetation that imparts colour • reduce/eliminate chemical dosages and allow zooplankton to re-establish and control green algae	• Water Quality and Watershed Management, pages 26–28. • Appendix 3 Using Copper Products..., pages 128–129.
	• test for dissolved organic carbon	• use coagulants in the dugout or in home treatment to remove	• Steps in Water Treatment, pages 84–88.

Symptom 6 Mineral Scale and Grey Discolouring of Clothes

Possible Causes	*What to Check For*	*How to Correct (Options)*	*For More Information See Section On:*
Calcium and magnesium hardness	• scale on plumbing fixtures, humidifier • grey colouring of clothes • test for hardness • gravel infiltration trench	• install ion-exchange water softener • use water additives such as Calgon, etc. • install a direct intake	• Steps in Water Treatment, pages 84–88. • Intake Systems, pages 44–47.

Symptom 7 Taste and Odour in Water

Possible Causes	*What to Check For*	*How to Correct (Options)*	*For More Information See Section On:*
Iron in water	• refer to Symptom 5 for comments		
Sloughy, musty, fishy smell	• algal growth	• use algal control techniques • install activated carbon filtration	• Dugout Management Practices, pages 102–110. • Steps in Water Treatment, pages 84–88.
Rotten egg smell	• refer to Symptom 3 for comments		
Salty, bitter taste	• high total dissolved solids caused by groundwater seepage or increased mineralization in gravel trench	• prevent poor quality water from seeping into dugout or relocate dugout • replace gravel filter trench with floating water intake	• Dugout Siting, pages 29–30. • Intake Systems, pages 44–46.

Glossary

absorption – a process by which one substance is trapped throughout the volume of another, usually a liquid by a solution.

adsorption – a process by which a substance is trapped on the surface of a solid substance.

algae – single-celled plants, capable of photosynthesis.

alkalinity – the ability of a solution to neutralise acids.

aquaculture – production of aquatic plants or animals, particularly fish, for commercial purposes.

aquifer – an underground layer of relatively porous, saturated rock or rock that is capable of yielding a useful supply of water.

AF – Alberta Agriculture and Forestry (provincial ministry).

backwashing – the cleaning cycle of a water treatment system where clean water is forced back through the filter media.

bacteria – single-celled organisms that do not contain chlorophyll and are not capable of photosynthesis.

bentonite – a swelling clay used to construct liners for lagoons and dugouts.

blue-green algae – common expression used to refer to cyanobacteria, an aquatic microorganism which can produce powerful toxins.

bluestone – copper sulphate.

BMPs – beneficial management practices.

coagulation – the addition of certain chemicals to water that allow very small particles to collide, stick together, and form flocs.

cfu – colony forming units.

total dissolved solids (TDS) – the sum of the weights of all mineral compounds dissolved in a specific volume of water.

turbidity – a measure of the light-scattering effect of small particles suspended in water.

ultra-violet disinfection – a water purification process using ultraviolet (UV) light to kill micro-organisms by disrupting their DNA and preventing reproduction. In order to be effective, UV must actually strike the cell.

virus – a large group of submicroscopic organisms consisting only of a core of RNA or DNA which is surrounded by a protein coat. Many viruses cause disease in humans.

watershed – the area of land that drains runoff to a point on a stream or other water body. Also called a drainage basin.

wet well – a structure installed next to a surface water supply, rather than directly in it, to provide a safe and convenient location for a distribution pump.

zooplankton – a diverse group of tiny aquatic animals that feed on algae and bacteria.

Appendix 1 Alberta Provincial Regulations

Approvals and Water Licensing

The *Water Act* establishes that the Crown, the Province of Alberta, has ownership of all water. In Alberta, no license is required for household purposes **up to** 275,000 Imperial gallons (1250 cubic meters of water) per year. Under the *Water Act*, household purposes are defined as water used for human consumption, sanitation, fire prevention, and watering animals, gardens, lawns, and trees.

Approvals to construct a dugout are required for dugouts that:

- are located in areas that have an AESRD Approved Water Management Plan
- are located in a watercourse frequented by fish or in lake or wetland
- would change the flow of water on an adjacent parcel of land
- have a capacity greater than 2500 cubic metres (550,000 gallons)
- are located in the same parcel of land as an existing dugout.

Using water from dugouts is exempt from licensing if:

- water is naturally impounded in the dugout from surface water runoff and no pumping has been done to facilitate the impoundment
- the dugout is not situated within a watercourse, lake, or wetland at any time
- the capacity of the dugout is less than 2,750,000 Imperial gallons (12,500 cubic metres)
- the total withdrawal of water from the dugout is less than 1,375,000 Imperial gallons (6250 cubic metres) per year.

For more information, contact Alberta Environment and Parks 310-0000 .

Fish Stocking

Recreational and/or commercial licenses are required to stock fish in a dugout. The licenses are issued by Alberta Agriculture and Forestry in Edmonton and may be contacted by phoning 310-FARM (3276). Licenses may also be required by Alberta Environment and Parks if dugouts are not used for household purposes and do not qualify under the exemption noted above. For technical information on fish farming, contact the AF Aquaculture Group in Lethbridge.

Setbacks

Alberta Transportation requires a minimum setback of 40 metres (131 ft.) from the highway property line on all primary and secondary highways. Local counties and municipalities also have similar setback distances from their roads for safety purposes. For further information, and to determine if a development permit is required, contact your local county or municipality office as well as the nearest Alberta Transportation office.

Technical and Financial Assistance

For technical assistance and information about possible funding opportunities, contact the nearest Agriculture Water Specialist with Alberta Agriculture and Forestry at 310-FARM (3276).

Appendix 2 Water Quality Guide

Table 1 Causes and Symptoms of Some Waterborne Diseases

Disease	*Microbiological Agent*	*Symptoms*
Bacterial gastroenteritis	Bacteria –various organisms including E. coli	Diarrhea or bloody diarrhea, abdominal cramps, fever, nausea, vomiting
Campylobacteriosis	Bacteria – campylobacter jejuni	Fever, abdominal pain, diarrhea or bloody diarrhea, nausea, vomiting
Cryptosporidiosis	Protozoa – cryptosporidia	Diarrhea, abdominal discomfort, slight fever, nausea, vomiting, headaches
Cyclospora infection	Protozoa – cyclospora	Diarrhea, bloating, abdominal cramps, nausea, vomiting, fever
Giardiasis	Protozoa – giardia	Diarrhea, abdominal cramps, nausea, vomiting, chills, headache, fever
Hepatitis	Virus – hepatitis A	Fever, chills, abdominal pains, jaundice, dark urine
Shigellosis	Bacteria – shigella	Diarrhea, or bloody diarrhea, fever, abdominal cramps
Typhoid fever	Bacteria – Salmonella typhi	High fever, headache, constipation, loss of appetite, diarrhea, vomiting, abdominal rash
Viral gastroenteritis	Viruses – Norwalk type, rotaviruses, adenoviruses, enteroviruses	Diarrhea, vomiting, fever, headache, abdominal cramps

Table 2 Chemicals and Their Associated Risk to Human Health

Chemical	Source	Potential Health Effect	Canadian Drinking Water Quality Guideline (mg/L)
Aluminum	Natural deposits in earth and aluminum-based coagulants	Unknown; unproven links to Alzheimer's and Parkinson's diseases	Under review
Barium	Natural deposits in earth	Circulatory system effects	1
Boron	Natural deposits in earth	Damage to reproductive system	5
Copper	Natural deposits; corrosion products from piping	Gastrointestinal irritation at levels much higher than guideline	1*
Lead	Natural deposit and corrosion products from piping, solder, and some brass alloys	Damage to kidneys, reproductive and nervous systems; development damage in young children	0.01
Nitrate	Fertilizers; human or animal wastes	Methemoglobinemia in infants under six months; unproven link to some cancers	45
Pesticides (including various fungicides, herbicides, rodenticides and insecticides)	Agricultural activities (spraying and water runoff)	Various effects depending upon type of pesticide; suggested links to cancers; damage to liver, kidneys, nervous and reproductive systems	Varies depending upon pesticide (see Health Canada website or contact local health authority for specific details)
Petroleum hydrocarbons	Leak in fuel oil or gasoline tanks allowing seepage into water	Some hydrocarbons have been linked to various cancers; damage to liver, kidneys, nervous system	Under review
Phytoplankton toxins	Natural toxins produced and released by microscopic plants and algae	Liver and nervous system damage	Under review
Sodium**	Natural deposits in earth	Health risk only for individuals on salt-restricted diets	200**
Sulphate	Natural deposits in earth; some fire-cutterits	At elevated levels causes laxative effect leading to dehydration	500***
Trihalomethanes	By-products of disinfection of water	Cancer	0.1****
Turbidity	Suspended mineral or organic matter	Shelters pathogens from disinfection; increases an requirement for disinfectant	1 NTU*****

* Guideline established based on aesthetic quality. Adverse health effects are possible at levels much higher than guideline.
** Guideline established based on aesthetic quality. Adverse health effects possible only for those on salt-restricted diets.
*** Guideline established based on aesthetic quality. Consumption of water with elevated levels of sulphates may result in gastrointestinal irritation including diarrhea.
**** Average of four quarterly samples.
***** Nathelometric Turbidity Units.

Table 3-1 Microbial Agents and Microbiological Agencies Affecting Livestock Health of Water

Chemical Species	Source	Symptom
Calcium	Natural deposits dissolving	Hard water, curdle soft deposits in kettles and water heaters
Copper	Natural deposits corrosion products from piping	Green staining of fixtures, metallic taste
Hydrogen Sulphide	Present in water with high	Rotten egg odour
Iron	Natural deposits and iron based coagulants	Rusty reddish brown staining of fixtures and laundry, metallic taste
Iron bacteria	Bacteria feeding on iron in water	Reddish brown slime in fixtures
Magnesium	Natural deposits	Hard water, curdle and deposits in kettles and water heaters
Manganese	Natural deposits	Black staining of fixtures and laundry, metallic taste
Sodium	Natural deposits	Salty taste
Sulphate	Natural deposits, some fire	Objectionable taste
Sulphide	Bacteria feeding on sulphur in water	Rotten egg odour, blackish slime in fixtures
Tannins and humic acids	Natural organic matter decaying plants and animals	Brown stains on fixtures, filmy, musty, earthy, woody and spicy
Turbidity	Excessively fine sand or silt, overall dark soil	Muddiness in water, cloudiness or color in water
Zinc	Natural deposits corrosion products from plumbing	Objectionable metallic taste

Appendix I Using Copper Products in Control Cynnalwriaeth

The Tuning of Copper Systems

Calculating a Copper Zone

- Formula for Granular Copper-Based Products

$$\frac{1}{\text{Percent (\%) Copper (Cu) in registered product}} \times \text{Diguot Volume to be Treated (in cu. feet)} \times \text{Treatment Dosage (milligrams per liter)} \times \frac{1\ \text{gram}}{1000\ \text{milligrams}} \times \frac{1\ \text{kilogram}}{1000\ \text{grams}} = \_\_\_\_\_\ \text{kilograms}$$

- Formula for Liquid Copper-Based Products

$$\frac{1}{\text{Percent (\%) Copper (Cu) in registered product}} \times \text{Diguot Volume to be Treated (in cu. feet)} \times \text{Treatment Dosage (milligrams per liter)} \times \frac{1\ \text{gram}}{1000\ \text{milligrams}} \times \frac{1\ \text{kilogram}}{1000\ \text{grams}} = \_\_\_\_\_\ \text{Liters} \left(\frac{*\ \text{specific gravity}}{}\right)$$

*Specific gravity of liquid product being used.

Note: Contact the Canada Pest Management Regulatory Agency for a list of registered copper-based products for the control of algae in diguots.

For further information regarding the use and application of copper-based products for algae control, contact an agriculture worker specialist with Alberta Agriculture and Forestry at 310-FARM (3276).

How to Apply Copper Treatments

Read the label and product literature for any restrictions on product use. Use a sub-target dose as recommended on the label, being careful not to exceed the label rate.

Although cyanobacteria may be controlled, even during a diguot with copper, they remain a widespread nuisance in the growth of green and brown algae.

Dilute the required amount of copper product into a volume of water so that it can be sprayed over the surface of the diguot. Spray the entire surface, with particular focus on areas where cyanobacteria populations are greatest. Spraying can be done from shore or from a boat. Alternatively, dry copper chemical can be put into a nylon sock, with ropes tied to both ends of the sock. Drag the chemical sock back and forth along the top of the water, covering the entire surface area. The dry compound will dissolve in the water. Spot treatment is also possible using one teaspoon (5 mL) of PMRA licensed dry copper sulphate product added to 1 gallon (5 litres) of water. Spot treat by spraying areas where cyanobacteria are starting to grow. Spot treatment may be useful when wind blows the bacteria against one shoreline.

Inspect the diguot once per week after treatment. Blooms can grow and die off within a one to two week period. A diguot should not be treated with copper more than four times during one open water season.

Appendix 4 Contacts

Alberta Agriculture and Forestry
J. G. O'Donoghue Building
7000 - 113 Street
Edmonton, Alberta T6H 5T6
Phone: 310-FARM (3276) Fax: (780) 422-0474
Website: http://www.agric.gov.ab.ca

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